XXXII. *On the Structure of Lavas which have consolidated on steep slopes; with Remarks on the Mode of Origin of Mount Etna, and on the Theory of "Craters of Elevation."* *By Sir* Charles Lyell, *F.R.S.*, *D.C.L.*

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Part I.

* [This paper was read to the Royal Society on the 10th of June, 1858, and a full abstract of it was printed in the 'Proceedings' for that month. In September of the same year I revisited Naples and Sicily, for the sake of re-examining certain points in the geology of Vesuvius and Etna, devoting five weeks to the exploration of the latter mountain. The additional facts and inferences obtained at that time have, by leave of the Council, been embodied in the present memoir; all the newly-intercalated passages being marked by *brackets*, thus [ ], or such as are simply recasts of the original MS., thus ∞[ ]∞. By comparing the abstract published in June (Proceedings of the Royal Society, June 10th, 1858) last with the present memoir, it will be seen that they agree with each other in all essentials, whether of fact or theory.]

Part II.

Part III.

APPENDIX.

PART I.

ON THE STRUCTURE OF MODERN LAVAS WHICH HAVE CONGEALED ON STEEP SLOPES.

Preliminary remarks on the characters commonly attributed to lavas which have consolidated on steep slopes, and on the theory of "Craters of Elevation."

THE question whether tabular masses of lava having a compact and stony texture, and a thickness of many feet, can be formed on slopes inclined at angles of from 10° to 40°, has of late years acquired considerable importance, since geologists of high authority have assumed that if the inclination exceed 5° or 6°, a lava-current will be scoriaceous in texture, fragmentary in structure, and insignificant in thickness. Such steeply-inclined currents, it is said, can never give rise to beds of compact rock, comparable to those solid layers which we see, alternating with scoriæ and tuff, in the older parts of volcanic mountains, such as the escarpments of Somma in the case of Vesuvius, or the cliffs surrounding the Val del Bove in the case of Etna.

It has even been laid down as a rule by one geologist of eminence, the late M. DUFRESNOY of Paris, that lavas, to be compact and crystalline, must have consolidated on a slope not exceeding 1° or 2°. He states, in his memoir on "Vesuvius and its Environs" (1834), "Les laves ne sont compactes et cristallines que lorsqu'elles se sont répandues sur un sol ayant 1 degré à 2 degrés au plus d'inclinaison. . . . . Lorsque la pente du terrain est supérieure à 2° la texture compacte commence à s'effacer, les laves deviennent bulleuses et même scoriacées. Les coulées, qui se présentent sous un angle de 4° ne sont plus que des agglomerations de fragments incohérents*." M. ELIE DE BEAUMONT, in his

* "Terrains volcaniques des environs de Naples," Mém. pour servir à une description géol. de France, tome iv. p. 342.

"Recherches sur le Mont Etna," says (in the same volume, p. 184) that the solid beds of ancient lava in the Val del Bove (which dip often at 28° and upwards) resemble those portions only of a modern current which have flowed over ground almost flat, or not sloping at an angle of more than 3°. And again, speaking of the Vesuvian lavas seen in the Fosso Grande, he observes, "they attain a thickness of 4 or 5 metres when horizontal, but are thin on slopes of 5° or 6°" (ib. p. 169).

From these premises it has been logically inferred that almost all volcanic mountains, whether active or extinct, have acquired their present conical form, not by eruption, or the reiterated outpouring of lava and outthrow of ashes from one or more central craters, but by upheaval, or the upward and outward pressure of gases and fluid matter rising from below and disturbing the position of lavas and tuffs previously horizontal. For wherever we obtain access to sections displaying the internal structure of large volcanic cones, we find a series of stony layers several feet or yards in thickness, inclined at angles of from 10° to 30°, and sometimes, though rarely, more than 35°; and if it be true that the law above laid down does really govern the congelation of melted matter, the whole excess of dip above 2°, or according to some authorities above 5° or 6°, must have been due to mechanical force, or to some cause capable of altering the original position of the beds. Accordingly the following hypothesis has been suggested:—A dense series of horizontal or nearly horizontal sheets of lava and scoriæ having been deposited, a force operating from below and exerting a pressure both upwards and outwards from a central axis towards all points of the compass, has uplifted suddenly the whole stratified mass and made it assume a conical form, giving rise at the same time, in many cases, to a wide and deep circular opening at the top of the cone, an opening called by the advocates of this hypothesis a "Crater of Elevation."

When I first visited Vesuvius and Etna in the autumn of 1828, I was so struck with the analogy of the ancient and modern portions of those volcanos, that it appeared to me in the highest degree unphilosophical to imagine that they could owe their form to operations differing in kind or degree from those witnessed during ordinary eruptions. Seeing that the injection of lava into fissures, and the consequent formation of dikes, had occurred in the most modern part of the cone of Vesuvius, I included dikes among the products of ordinary eruptions, and inferred that an adequate lapse of years alone was required to reproduce gradually such volcanic mountains as had been formed in the course of previous ages. My grounds for adopting such an opinion were stated fully in the first volume of my 'Principles of Geology,' published in 1830 (see pp. 345, 394, chaps. 20 and 22), in which, as well as in the third volume published in 1833 (p. 84), I objected to the theory of Elevation-craters, first propounded by the late Baron Leopold von Buch.

Mr. Scrope, in his 'Considerations on Volcanos' (1825, p. 156, § 4), had previously advocated the same views, and had dwelt emphatically on the increase both in solidity and bulk imparted to volcanic cones, by the injection of lava into fissures in the heart of the mountain. He had moreover admitted, in a paper read to the Geological Society

in 1827, in which he combated Von Buch's theory of "Erhebungskratere," that the frequent earthquakes which accompany eruptions and are connected with the injection of lava from below, imply the expansion of the solid framework of the cone, but he still insisted on the doctrine that "the parallel and sloping beds which with a quâquâversal dip compose every volcanic cone, were not originally deposited horizontally, or otherwise than at a high angle of inclination, and the angular elevation they have since sustained is in general comparatively trifling*." Yet neither Mr. Scrope nor I, when we ascribed a volcanic cone to the cumulative effect of reiterated eruptions, claimed any originality for so obvious an explanation of the phenomena. For true it is, as M. Elie de Beaumont had remarked, that "Philosophers and geologists, who from the time of the Greeks to our own days have seen Etna covering its flanks with new beds of ashes, scoriæ and lava, have admitted, almost without examination, and as a self-evident fact, that the entire mountain is simply the result of the gradual addition one over the other of elements mutually similar, and all resembling the products of the eruptions which they themselves have witnessed" (ib. p. 101).

After the publication of the memoirs above cited of MM. Dufresnoy and E. de Beaumont, all geologists who implicitly acquiesced in the doctrine laid down by them as to the law which governs the consolidation of lava, became, almost unavoidably, converts to Von Buch's hypothesis; for it was not only necessary to admit a vast amount of upheaval, but to assume that the whole of it had in each volcano been posterior in date to the outpouring of all, even the latest of the highly-inclined lavas, found in each cone.

Without attempting in this place to sketch the progress of a long controversy to which this question gave rise, I may refer to M. d'Archiac's able analysis of the memoirs relating to it, in the first volume of his 'Histoire des progrès de la Géologie,' published in 1847, in attestation of the deep impression which the "Elevation-crater" theory had then made on the minds of not a few of the most experienced geologists in Europe. At the same time, it will be seen in the same chapter that some strong protests were made against it; one in particular by my friend the late M. Constant Prévost, in his account of the new volcanic island which rose in the Mediterranean in 1831. Ascribing its origin to eruption and not to upheaval, he took an opportunity in that memoir of adducing arguments derived from the structure of Vesuvius, Etna and other mountains, against the theory of Von Buch†.

After I had given in successive editions of my 'Principles of Geology,' from the first to the ninth, and in a paper on the structure of volcanos, published by the Geological Society in 1849‡, my reasons for rejecting the "Crater-of-elevation" theory, I visited Madeira in 1853–54, and examined its structure, in company with Mr. George Hartung of Königsberg. We went also together to the Canaries, where we studied the island of Palma, which had been expressly selected by Von Buch as a type of what he styled a

* Trans. Geol. Soc. London, 2 Ser. vol. ii. p. 341, 1827.

† Mém. de la Société Géol de France, vol. ii.

‡ See 'Proceedings' for that year, p. 207.

"Crater of Elevation." These explorations convinced me more than ever of the untenable nature of the hypothesis which attributes so preponderating an influence in the formation of volcanic cones to movements from below, whether paroxysmal or gradual, whether concomitant with, or posterior to, the accumulation of the successive products of eruption*.

In the course of my examination of Madeira and Palma, I had seen modern lavas, inclined at high angles from 15° to 20°, which had evidently not changed their position from the time of their origin, and which nevertheless were in great part of stony structure. Mr. HARTUNG, during a visit to Lancerote, one of the Canaries, in 1855, observed a basaltic lava, compact and continuous, which had congealed on the side of a modern cone called the Corona, at an angle of 30°, and which he traced for a space of 20 feet down the steep slope, the thickness of the layer increasing from 2 to 4 feet, with a breadth of about 35 feet. This current was not more vesicular than some of the oldest lavas of Madeira or of Etna.

Mr. DANA also, in his 'Geology of the Exploring Expedition of the United States' (1849), had remarked that the lava of Mount Loa, one of the Sandwich Islands, cools so suddenly, as to be capable of consolidating on steep slopes, sometimes of 25°.

But no observation was so much in point, in reference to this question, as that made by Signor SCACCHI, who in 1850 saw a compact stony lava, which in that same year had flowed down the flanks of Vesuvius, from near the margin of the great crater to the base of the cone in the Atrio del Cavallo, having a thickness of from 1½ in the upper to 4½ feet in its lower part, and dipping at angles varying from 32° to 38°. The interior of this current was laid open to view by a rare accident, namely, the sinking down, in February 1850, of a certain portion of the north flank of the cone, whereby one side of the new lava-stream was engulfed, and a section of the interior of the remainder rendered visible. This lava produced scarcely any scoriæ, whether above or below it, and exhibited hardly any vesicles in its texture. Although it had cooled on an average declivity of 35°, there was no distinction, in regard to compactness of texture, between it and those lavas of known date at the foot of Vesuvius that have congealed on perfectly level ground †.

* For observations on the structure of Palma, made by Mr. HARTUNG and myself in 1853–54, and theoretical conclusions thereon, see p. 498 *et seq.*, of LYELL's 'Manual of Geology,' 5th edition, 1855.

† SCACCHI, Memoria sull' incendio Vesuviano del 1850 et 1855, pp. 44, 65, and 145.

[Professor PIAZZI SMYTH informs me that in 1856 he observed, within 1700 feet of the summit of the Peak of Teneriffe, at the Alta Vista, a point 10,500 feet above the level of the sea, a bed of dark green obsidian with crystals of glassy felspar, resting on an average slope of 28°. The thickness of the inclined lava (the interior of which has been laid open partly by aqueous action and partly by fractures assisted by gravity) is from 3 to 7 feet. The rock is dense and compact in its lower part, but vesicular towards the surface, from which a covering of pumiceous scoriæ appears to have been washed away. The width of the lava is 200 feet, and it was traced for about 250 feet down the slope of the cone. Dips of 15° and 25° were seen in the solid continuous layer, which is very modern with reference to the Peak and the uppermost of all the lavas on the ridge where it occurs; but powerful streams of still later date, having an aggregate depth

After reflecting on these and other analogous facts, I was desirous, before publishing in detail the observations which Mr. Hartung and I had made in Madeira and the Canaries, to revisit Vesuvius and Etna, which I accomplished in the autumn of 1857. In studying Mount Etna, my attention was principally directed—1st, to the lithological character of those modern lavas which have consolidated on steep slopes; and 2ndly, to the question whether any proofs can be found, in the position of the ancient lavas and tuffs of the great volcano, in favour of the doctrine that the upheaving rather than the eruptive force has exerted a dominant influence. I hope at no distant time to offer to the Society the results of my observations on Vesuvius and some of the cones and craters of the Phlegrean fields, considered in reference to the same questions.

Recent Shower of Ashes of Sept. 1857 *from Etna.*—On my way to Catania (October 1857), I was shown, when passing through Aci Reale, some of the pulverized scoriæ which had been showered down on that city a few weeks before, on the 6th of September, 1857, from the summit of Etna, no less than fourteen miles distant. I was informed, that while this dust was falling on the roofs of the houses and pavement of the streets, loud detonations were heard at Aci, and a whirling column of dense smoke was seen to rise from the crater. The shape of the cone at the same time underwent a marked change, in consequence of which it now deserves even more than formerly its ancient epithet of "bicornis." [When I ascended to the summit of Etna, October 1858, I found that this same fall of sand and lapilli, being a hundredfold more voluminous near the focus of eruption, had levelled up the superficial irregularities of the lava of 1838, lying at the eastern base of the cone to such an extent that I could cross it with my mule. I also saw large angular fragments of a dark dolerite, 3 or 4 feet in diameter, thrown out at the same period to great distances from the crater, and resting on the gently inclined slope S.E. of the base of the cone. My guides assured me that the highest part of the rim of the crater had lost much in height during these explosions.]

Alluvial deposits and external features of the coast along the eastern base of Etna.

∞[When travelling by the coast road along the eastern base of Etna, the geologist cannot fail to be struck with the extent and thickness of an alluvial deposit, from 50 to 150 feet thick, which skirts the shore from as far north as the Fiume Freddo to as far south as Prajola, a distance of about ten miles. This alluvium, as I afterwards learnt, stretches inland for three or four miles, forming a terrace or platform on which several towns, such as Giarre, are situated. It contains fragments of such rocks as I

of from 100 to 300 feet, have flowed down on each side of the ridge. These newer lavas, which are very similar in composition to the older, are fragmentary, like those of Etna, *on the surface*, or broken up into pieces for a depth of several feet; but no section affords an opportunity of determining whether they contain solid beds in the interior.

Professor Smyth has advocated Von Buch's theory of upheaval in reference to the more ancient parts of Teneriffe, but regards the central or modern cone, to which the above-mentioned inclined beds of porphyritic obsidian belong, as a cone of eruption.]

remembered to have seen when I visited Etna in 1828 among the old lavas and dikes of the Val del Bove. Hence I was led to inquire whether these transported masses, some angular, others rounded, the larger ones often more than 5, and in some cases 9 feet in diameter, might not, together with the associated sand and gravel, bear testimony to the gradual excavation by aqueous erosion of that vast crateriform cavity which forms the principal feature of the eastern flank of Etna.

No small portion of the alluvial deposit, particularly where the thickness of the mass and size of the blocks are most conspicuous, lies exactly opposite the Val del Bove, in the low region to which the few torrents which still drain it in the rainy season carry down their tribute of sand and boulders. The area occupied by the old alluvium is accurately laid down on the great map which accompanies Baron S. von Waltershausen's splendid work, now in the course of publication, entitled 'Atlas von Etna,' to which I shall often have occasion to refer in the sequel. A reduced copy of the map accompanying that valuable monograph is given, with the author's kind permission, as one of the illustrations of this memoir (Plate XLIX.). The nature and geological age of the alluvium will be more fully discussed when I treat of the probable origin of the Val del Bove.

Another feature which arrests the geological traveller's attention as he passes along the coast at the base of the great volcano, is a series of terraces which terminate abruptly in escarpments facing eastwards and resembling sea-cliffs. This character in the physical geography of the country prevails throughout the fertile region, extending for more than twenty miles north of the city of Catania and three or more miles west from the sea to a height of 1000 feet and more above it, and is equally observable, whether the country consists of marine tertiary clay with associated basaltic rocks, as at Trezza, Aci Castello and Catira, or is composed of lavas of subaërial origin, as at Aci Reale, or of the alluvium already alluded to, as at S. Leonardello. The ancient cliffs are often from 300 to 600 feet in height; some of them two or three miles inland, others, as in the case of Aci Reale, having their base still washed by the waves.

Reasons will be given in the sequel for concluding that this line of coast has been gradually upraised and made to emerge in comparatively modern times; and it will be shown, among other proofs, that littoral shells of recent marine species are met with here and there on the surface, as high as 40 feet or more above the sea-level, in a fresh state and retaining much of their original colour. A similar upheaval prevailing for a much longer period, and affecting somewhat uniformly considerable areas, has carried upwards the whole of the adjoining land, perhaps the whole mass of Etna and much of the surrounding non-volcanic territory, raising it bodily a thousand or more feet above its former level, and giving rise to those ancient inland cliffs above alluded to.

When we try to determine the relative age of the various geological monuments connected with these movements, we find the task more complicated than where we have simply to deal with rocks of subaqueous origin, such as have been slowly uplifted and made gradually to rise out of the sea. For beside the successive rise and denuda-

tion of the masses once submerged, we have in this instance to allow for the contemporaneous building up above the waters of a great volcano thousands of feet high, as also for the flowing down from it of lava-currents, some of them partially or entirely masking the old inland cliffs, or having reached the coast so as to convert tracts of sea into land. The deltas, moreover, of torrents which have derived nearly all their sand, pebbles, and transported blocks from the volcanic formations of various dates, have in their turn been uplifted, so that the alluvial accumulations before alluded to of comparatively modern date, now constitute terraces terminating in low inland cliffs. It is necessary, therefore, to bear in mind all these and other peculiarities in the physical geography of this region, before we can understand the position of some of the lavas about to be described.]

Highly inclined stony lava of Aci Reale.

The town of Aci Reale*, situated about twelve miles north of Catania (see Map, Plate XLIX.), stands on the top of a cliff, in which a platform, elevated at some points near the town, more than 650 feet above the sea, ends abruptly. The slope of the inclined plane forming the summit of this platform is usually at an angle of three or four degrees, but is occasionally steeper, and is prolonged two or three miles inland. The precipice between the town and the sea is in many parts perpendicular, although a line drawn from the top to the bottom would rarely exceed 45°, and in some parts would only amount to 35°. In the face of the cliff are exposed the truncated edges of those seven lava-currents which were noticed by the Canon Recupero in his 'Storia Naturale dell' Etna,' and to which the traveller Brydone called attention in England, by stating in one of his 'Letters on the two Sicilies,' that Recupero had been able by the aid of these lavas, "to assign a higher antiquity to Mount Etna than had heretofore been ascribed to our planet itself." Dr. Carlo Gemmellaro assures me that he has verified the accuracy of the Canon's descriptions, especially the fact, that at no less than seven different levels there intervene, between successive currents of lava, red layers either of burnt tuff or of decomposed scoriaceous crusts of lava-currents, which have been baked and reddened by heat, or as Professor Bunsen would say, by "fumerolic action" superinduced by the incumbent lava. Five of these brick-red bands I saw myself in one vertical section at the Scalazza, a spot of which I shall presently have more to say. They reminded me precisely of the red clays and tuffs which abound in the Island of Madeira, where many subaërial lavas have overflowed the surface in succession, and where there have been sufficient intervals of time between successive eruptions for the decomposition into clay of the crust of each preexisting lava, or where volcanic sand has been showered down from above or washed over the older lava by torrents and floods.

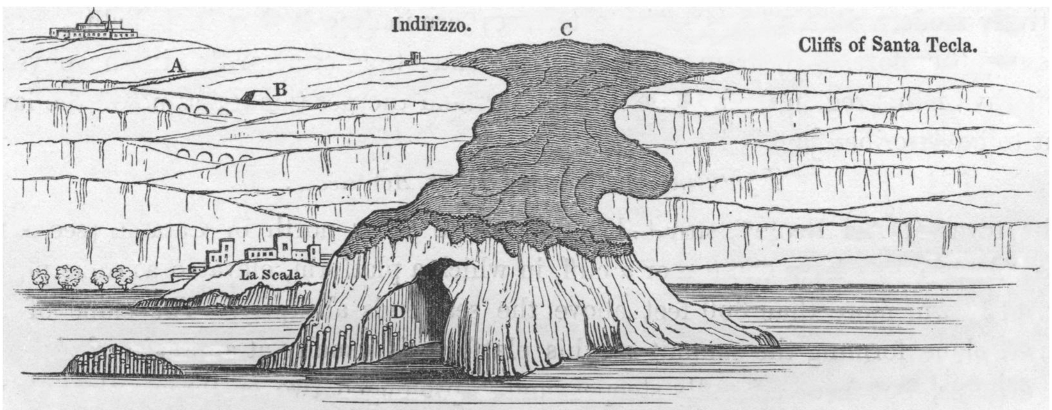
We need not, however, seek illustrations of such a phenomenon in distant regions, since in the suburbs of the neighbouring Catania similar baked and altered soils of a

* When I first examined the cliffs of Aci Reale (October 1857), I was accompanied by a skilful young geologist, Signor Gaetano Giorgio Gemmellaro.

red colour are to be seen at the contact of the lava of 1669, with ground which before that year was highly cultivated

The cliff of Aci Reale above mentioned and represented in the accompanying rough sketch (fig. 1), for which I am indebted to the kindness of my friend Dr. CARLO GEMMELLARO, is about 500 feet high. It runs parallel to the sea for some distance north

Fig. 1.—*Cliff and coast at Aci Reale.*

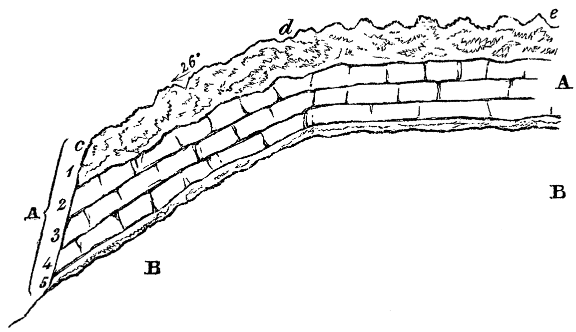


A. Upper part of the road called the Scalazza.
B. Bastione del Tocco.
C. Lava-current which descends the cliff to the Grotto delle Palombe.
D. Grotto delle Palombe.

and south of Aci. Seen from a boat, the lava-currents appear horizontal, because the section is transverse to their dip. They are, however, in reality inclined at angles varying from 4° to 7° seaward. Below the letter A (fig. 1) a zigzag road called the Scalazza, partly built on arches, leads down from the town to the village of La Scala. At the end of the second turn of this road, and about 150 feet below the summit of the platform (B, fig. 1), is a part of the fortification called the Bastione del Tocco, where an indentation occurs in the face of the cliff, probably made originally by the sea at the time when the precipice was undermined by the waves. This indentation affords the geologist a rare opportunity of seeing a longitudinal section of one of the lavas, the uppermost of the whole series at this point, exposed in the direction of its course from west to east. It consists of a powerful current dipping east or towards the sea at angles varying from 23° to 29°, and exposed for a length of 80 feet in the garden of one GIUSEPPE TORRISI. The mass has all the usual characters of an Etnean lava-current, displaying an upper and lower bed of scoriæ (A 1 and 5, fig. 2) with an intermediate stony portion (A 2, 3, 4), which in this instance is more than usually thick and compact. The upper scoriaceous crust (A 1, fig. 2) is about 12 feet thick, below which comes the stony portion (A 2, 3, 4) 20 feet thick, having a dip of from 23° to 29°, and divided into three beds, each about 6 or 7 feet thick, the lowest becoming at its base first cellular, and then vesicular and scoriaceous. The rock is a compact grey dolerite with numerous crystals of felspar, and some of augite with a small quantity of olivine. The

whole of these stony beds (A 2, 3, 4) are divided by joints nearly at right angles to the planes of bedding. The passage from the upper crust or scoriæ to the compact

Fig. 2.—*Section of lava inclined at 23° and 29° at the Bastione del Tocco on the Scalazza of Aci Reale.*



c, *d*. Section running east and west.

d, *e*. Section running from south to north, or at right angles to the dip.

A. Uppermost lava-current:—1, scoriaceous crust; 2, 3, 4, compact, stony beds; 5, lower scoriæ.

B. Red or burnt surface of subjacent tuff.

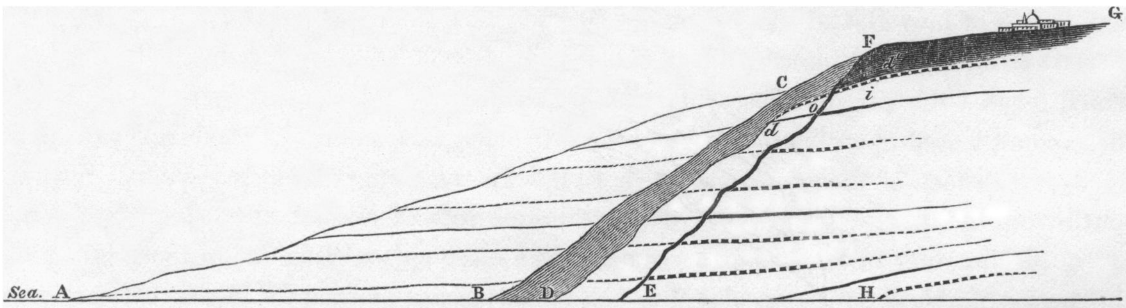
dolerite (A 2) is very abrupt, as is that from the lower part of the stony lava (A 4), where it becomes cellular to A 5, or the underlying scoriæ. This last is about 2 feet thick, and consists of small fragments for the most part agglutinated together. At its contact with the uneven surface of the subjacent tuff (B) it fits into and fills up the depressions several inches deep in that tuff, which is composed at the top of sand and lapilli burnt red for a depth of from 1 to 2 feet. Below this, but not visible at the point of section (fig. 2), is a coherent earthy tuff of fine-grained materials and a light brown colour, without lapilli, and divided somewhat regularly by joints, so as to have a columnar appearance.

[This fine-grained stratum rests on loose volcanic sand of a black colour, containing many heavy blocks of lava, more or less rounded, such as are seen in the beds of torrents which descend from the flanks of Etna. At the time of my second visit to Aci (1858), several of these hard blocks, from 12 to 16 inches in diameter, had just been dug out of the black sand in a vineyard adjoining the Bastione. The whole deposit, including the tuff, resembles the transported materials observable in the wide watercourses which furrow the western slopes and base of Etna. Below the above-mentioned tuff and loose sand is seen another current of lava 40 feet thick, also having red or burnt tuff below it, and below that again there appear, in the face of the cliff on the left hand as we descend the Scalazza, a series of other beds, among which are four lavas, each reposing on red and altered tuffs or soils.]

To return to the inclined dolerite of the Bastione: we have first to consider whether it can possibly have acquired its present dip, averaging about 26°, in consequence of a landslip or any other movement posterior to its original congelation. That it has not done so, is demonstrated by the fact that it is a continuous part of an unbroken and uninterrupted lava-current, the uppermost part of which can be traced for several hundred

yards westwards from F towards G (fig. 3), gradually rising 100 feet or more from the Bastione to near the top of the platform of Aci Reale. The crust of scoriæ is sometimes

Fig. 3.—*Section in part ideal of the lavas and of the ancient and modern cliff at Aci Reale.*



A, B, C. Portion of the lavas and tuffs supposed to have been removed by the sea.
B, C, F, G. Lava-current of the Bastione, of which a portion, B, D, F, C, was afterwards removed by the sea.
E, F. Existing cliff at the Scalazza.
o, *i*. East and west, or longitudinal section seen at the Bastione.
The interrupted lines - - - indicate the brick-red tuffs and soils torrified by the overlying lavas.

(as may be seen at the road-side on the Scalazza close to the Bastione), separated into irregular alternate layers of solid dolerite and beds of loose scoriæ. From the point where the natural section (fig. 2, p. 713, and *o*, *i*, fig. 3) presents itself, this upper crust unites without any break with the mass which we can follow, through gardens, and also in another line up a steep lane, to a point where the dip is gradually reduced to 15°. Still higher up the hill we arrive at the church of Santa Maria, where in the suburbs of Aci Reale, a lava, which I believe to be the same, has a dip of only 9°.

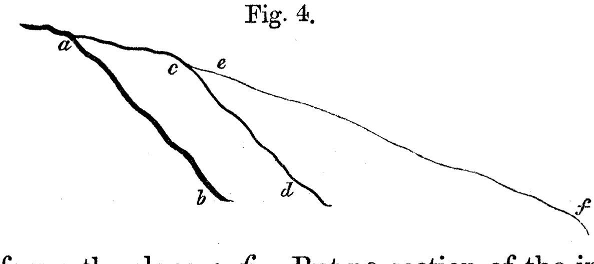
If the red stratum, indicated in fig. 3 by the interrupted line above *o*, *i*, on which the inclined dolerite of the Bastione rests, had consisted simply of a burnt soil derived from the decomposition of an older and subjacent lava, we might have supposed the unusually steep dip of 23° and 29° to have arisen from the accident of the newer current having at this point overflowed the terminal slope of a preexisting lava; for when lavas come to a halt (as is well exemplified by the newest of all the Etnean currents, that of 1852 in the suburbs of Zafarana), they commonly end in a steep wall, 20 and 30 feet or often more in height, and sloping at angles of from 20° to 35°, as represented at H, fig. 3. But this hypothesis is rendered untenable by the fact that the stratum of tuff and lapilli burnt red, is not the disintegrated surface of an underlying lava, but the upper part of a series of strata of tuff and loose black sand containing boulders, deposits such as we find in the wide channels of torrents on the flanks and near the base of Etna.

To explain, therefore, the steep inclination which the surface of the stratum (B, fig. 2, p. 713, and *i*, fig. 3) had acquired before the lava G, F, C, B reached the present site of the Bastione, I think it necessary to suppose that a sea-cliff (D, *d*, *o*, *i*) already existed, the top of the cliff consisting of beds of brown tuff and loose black sand, forming the mass *i* as above described, which as a whole was too incoherent to produce a precipice, but which

might, when the rocks below were undermined, have slid down and formed a slope of from 20° to 30°, as from *d* to *i*, fig. 3. The Bastione lava, after flowing over the platform from G to F and baking the underlying tuff at *i*, *o*, *d*, which it turned red, descended in a cascade to the foot of the old cliff D; but the sea immediately resuming its efforts cut away the new facing of lava B, C, F, and then encroached some yards further into the older rocks from D to E, in the same manner as it had previously swept away the lavas A, B, C, which formed the original eastward prolongation of RECUPERO's seven currents. After these complicated operations, the Bastione lava itself was made to end abruptly (as at *o*, fig. 3) in the face of the actual precipice E, F. In the Canary Islands, especially on the south-western coast of Palma, I have seen numerous lava-streams of modern date pouring in like manner in black sheets over the face of steep sea-cliffs, at the base of which the waves of the Atlantic are beating. So many years commonly elapse between two successive eruptions, and so many more before a second stream of lava happens to reach precisely the same point of the coast, that the sea has usually time to remove a part of, or all of the new facing of stone which for a season had protected the old cliff. Such inroads, however, of the ocean, though they check the advance of the land, cannot prevent the cliffs from gaining continually in height.

☞[By referring again to fig 1 (p. 712), the reader will see at and below C a representation of a great current of lava, to which my attention was first drawn by Dr. CARLO GEMMELLARO, whose interpretation of its position relatively to the ancient cliff of Aci I now am prepared to adopt after examining it in 1858. The lava (C) came down from the west or from the higher region of lateral cones over the platform of Aci, and its right margin is to be seen in the northern suburbs of the town at the church of Indirizzo (fig. 1), where its exterior or scoriaceous covering alone is visible. The more stony portions of the crust consist of a dark rock with crystals of felspar. The current, when it reaches the brow of the cliff, may be traced in gardens below C, descending a steep slope at angles of 23° and 28°, yet here and there houses are built on ledges of the rock. The more ancient parts of the cliff occurring south and north of the course of this current, whether on the Aci or Santa Tecla side, have a declivity of 35° and in some places 47°, being on the average 20° steeper than the newer lava. Thus, when viewed in profile from the south, the old cliff is represented by the lines *a*, *b* and *c*, *d* (fig. 4),

Fig. 4.



while the new lava forms the slope *e*, *f*. But no section of the interior of the mass *e*, *f*, much less of its junction with the face of the old buried cliff, is obtainable. Half-way down from *e* to *f* I found the same character in the lava, as above, at *e*. Near the sea,

below *f*, and not far from the Grotto delle Palombe, we see a longitudinal section for the space of 100 feet, the scoriaceous crust being removed by denudation. Here a central stony but not compact layer is laid open to view, 2 or 3 feet thick, with a dip of 25°. On the margin of the sea, we find below the scoriaceous crust, a stony mass, more than 20 feet thick, exposed in a vertical cliff, at the foot of which the waves have excavated a cavern 14 feet high, called the Grotto delle Palombe (D, fig. 1, p. 712), only approachable in a boat. Here the rock is compact and columnar, the erect and often well-shaped pillars being composed of a dark dolerite. Over the cave, in a bed of lava in which many fragments of scoriæ are involved, oblique and irregular prisms appear. Still higher up, a nearly horizontal stratum, 4 feet thick, with a vertically prismatic structure, is observable. As this coast has undergone, as before stated, p. 710, an upward movement in very modern times, it is possible that the lava of Indirizzo and of the Grotto delle Palombe may be ancient enough to have participated in the upheaval, in which case the columnar mass may have been at first submarine, and may have cooled on a gently sloping ledge of rock. We cannot, however, infer its original submergence from the prismatic structure alone, because we have innumerable examples in Auvergne and the Vivarrais of subaërial lavas, in which there are fine ranges of basaltic columns as perfect as any in the Giant's Causeway or Fingal's Cave.

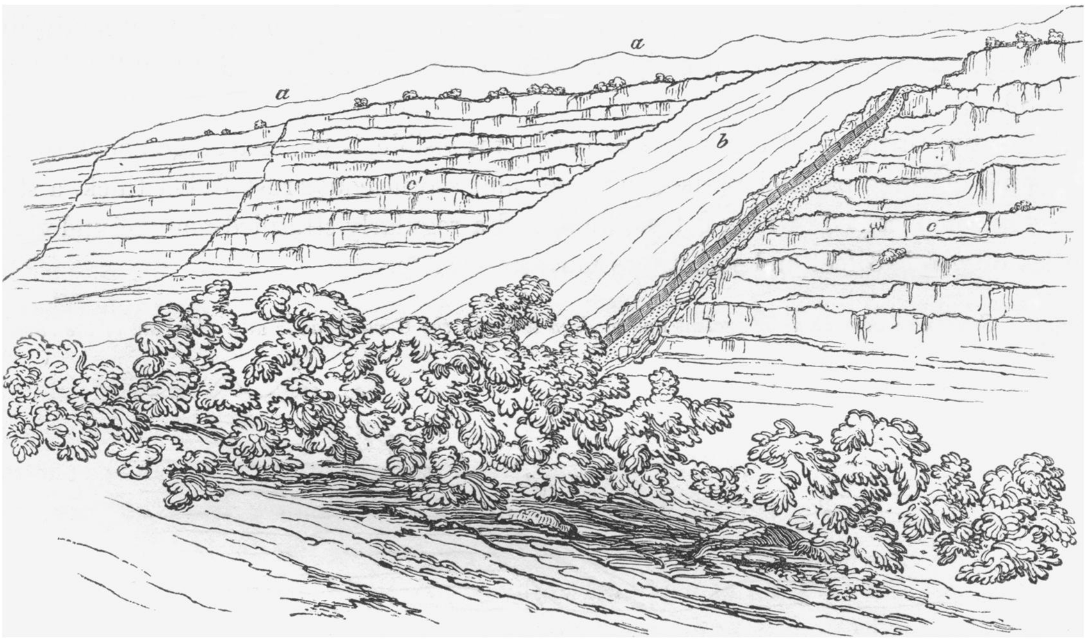
About a mile north of Santa Tecla, and nearly three miles north of Aci Reale, another much more modern lava, namely, that of 1329, is seen descending from the interior or region of lateral cones, and entering the sea at a place where the coast is much less lofty than at Aci, with a breadth, as will be seen by S. VON WALTERSHAUSEN's map, of about a mile. If we reflect on its position, as well as on that of many other lavas of different ages which have thus poured down one after the other over these sea-cliffs while the waves are always eating away the sea margin, the hypothesis above suggested in explanation of the steep slope of the tuff underneath the lava of the Bastione of Aci will not seem far-fetched or improbable. But in whatever manner we may account for that slope, it is undeniable that a mass of compact dolerite, 20 feet thick, exposed to view at the Bastione, has consolidated into compact rock, with a dip of 23°, 26°, and 29°; and had the sea removed as much of the current of the Grotto delle Palombe (or C, fig. 1) as I assume it to have done in the case of Aci at B, E, F, C (fig. 3, p. 714), a similar exhibition of stony beds dipping at angles as great or greater would I believe have been made. But this the reader will be more ready to admit when he has fully considered the section next to be described.

Highly inclined lava of Cava Grande.

From the Scalazza of Aci Reale, we journeyed (Signor G. G. GEMMELLARO and I, October 1857) by Giarre and La Macchia, and thence through part of the woody region to the great chestnut, called the "Castagno dei Cento Cavalli," which stands on a tufaceous deposit at a height of more than 2000 feet above the sea. We then went direct to Milo, and in our way fell in with a second fine example of a sheet of modern

lava, in this case of known date, conforming to a very steep slope, and having its internal structure remarkably well displayed. Our bridle-road led us round the head of a deep and narrow gulley, called the Cava Grande (see Maps, Plate XLIX. and L.), the largest of several which furrow this part of the eastern flank of Etna. Looking down the ravine, we saw on the right bank a stratified mass, turned edgeways towards us (*b*, fig. 5),

Fig. 5.—*Highly inclined lava of Cava Grande.*



a, a. Main stream of lava of 1689.
b. Branch of same lava (*c, d*, fig. 6), having a mean inclination of 35°.
c, c'. Right bank of ravine composed of older lavas.

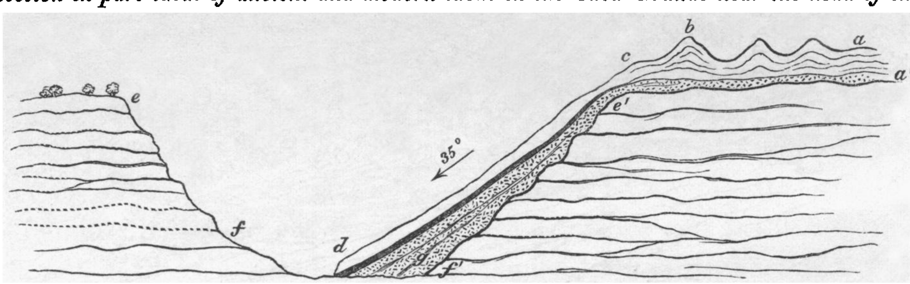
which I thought at first must be a portion of the beds of lava and scoriæ which had once belonged to the upper part of the cliff, and which, having been undermined by the torrent, had slid down the steep bank. But on nearer inspection we ascertained that the inclined mass (*b*, fig. 5) was a branch of *a*, *a*, or the great current of 1689, which flowed down from the Val del Bove in that year, and cascaded in the manner represented in the annexed drawing (fig. 5), over the right bank of the Cava Grande. The ramification of this current is very accurately laid down in the Map of S. von Waltershausen, copied in Plate L., where the date assigned to it is 1688; but Dr. Giuseppe Gemmellaro in his Map of Etna has given the date as 1689, and he tells me that the lava of the preceding year was confined to the Val del Bove.

For a great part of the year there is no water flowing in the Cava Grande, nevertheless occasional floods have in the course of ages excavated this deep narrow chasm, at the upper end of which we find, what is so common at the head of narrow valleys on the sides of volcanos, a perpendicular precipice, of a horse-shoe form, over which water falls in a cascade, which is gradually cutting its way backwards. [Although the channel was

dry at the time of my last visit (September, 1858), I witnessed several avalanches of sand and stones loosened by the heavy rains of the preceding day, proving to me how great must have been the waste of these cliffs in the course of the 170 years which have elapsed since the lava (*b*) poured over the right bank. The geologist is indebted to such annual waste not only for the section of the lower extremity of the lava, but also for that of its side, as shown in fig. 5, from which great fragments have broken away for a space of about 200 feet in length, many of them still strewed over the slope.] The ravine is about 220 feet deep, with walls in parts vertical, but whose mean inclination ranges from 38° to 65°, usually about 20° steeper than the branch of the lava (*b*) of 1689.

The entire thickness of the latter, so far as it is visible, is on an average about 16 feet, consisting of three parallel parts—an upper and scoriaceous crust 8 feet thick, a stony and very compact bed of rock 5 feet thick, and a regularly stratified mass of underlying scoriæ, of which 3 feet and sometimes more are visible.

Fig. 6.—*Section in part ideal of ancient and modern lavas in the Cava Grande near the head of the ravine.*



a, *c*. Lava of 1689, with lofty, parallel, east and west ridges.
c, *d*. Branch of same current descending the right bank of the Cava Grande, and inclined at 35° and higher angles, the dark central portion being compact, the rest scoriaceous.

The annexed section (fig. 6) is supposed to pass through the Cava Grande in a north and south direction, or at right angles to its course, and to intersect not only the newer lava of 1689 (*a*, *c*, *d*), but also the nine or ten older currents of Etna (*e*, *f*, and *e'*, *f'*) which constituted the walls of a ravine before the modern lava poured into it. The old currents alluded to appear horizontal in the diagram, because they are intersected at right angles to their dip. They are in fact inclined at about 7° eastward or towards the sea, each lava being on an average about 10 or 12 feet thick, and separated by fragmentary matter belonging to the top and bottom scoriæ of successive currents, or sometimes by tuff, *i. e.* volcanic sand and mud transported by land-floods or the winds. These partings are about equal in thickness to the solid beds, and exhibit at various heights red or burnt strata, as at *f*, three of them being conspicuous on the left bank.

To return to the branch of the lava of 1689, or *c*, *d*, fig. 6: I have stated that its central portion is quite compact. It contains crystals of felspar, but none of augite, a small quantity of olivine, no iron, and its specific gravity is that of an ordinary trap-rock. It is worthy of notice, that this central inclined layer surpasses greatly in compactness a

large part of the old rocks (*e*, *f*) in the cliffs of the right and left banks. The joints are few, often 9 or 10 feet apart, so that detached fragments of this stone, 9 feet in length and 5 feet high, may be seen strewed over the slope on the left side of *c*, *d*, fig. 6. The demarcation between the stony layer and bottom scoriæ is marked, whereas the passage of the same into the upper scoriæ is more gradual. [The normal thickness of the solid rock is 5 feet, where the inclination is 32° and 35°; but when near the top, as at *e*′, the dip increases to 45° and 47°, the thickness is reduced to one-half, or $2\frac{1}{2}$ feet, just as a stream of water, arriving at a steep part of its channel, increases in speed and diminishes in depth. Yet, when dipping at 47°, it is still not only stony and compact, but there is no breach whatever of continuity in the mass, and no more joints than in the less inclined portion.

The first operation which took place when the lava reached the edge of the ravine, seems to have been the rolling down of scoriæ from the frontal wall of the advancing current, so that the uneven sides of the ravine were levelled, and a sloping talus of loose scoriæ (*g*), for the most part inclined at 32° to 35°, was produced. But near the top, at *e*′, before the old precipice had been reduced to that more moderate inclination, the lava cooled at an angle of 47°, and might probably have consolidated on a still steeper slope. The width of the branch *c*, *d* must exceed 400 feet, and is therefore so great in proportion to its depth, that in a transverse section the central stony layer of 5 feet would be seen to form what might be termed a sheet of lava.

The traveller will at once see, by the state of the surface of this current and by its vegetation, that it is not a current of high antiquity. Except where cultivated or planted with trees, it is covered simply with lichens or with a few scattered shrubs, chiefly of broom. The superficial irregularities of the main current (*a*, *c*), when contrasted with the comparative evenness of the branch *c*, *d*, are very striking, the first inclined at 16° east, the other at 32° and 47° north. Indeed, the height of the parallel ridges, from *a* to *b*, no less than four of which come within a few hundred paces of the Cava Grande, is excessive, as is the steepness of their sides. The ridge *b* is about 40 feet high and 40 wide, its north side, or that towards the Cava Grande, sloping at an angle of 70°, its southern at 35° and 40°; the mineral composition of the concentric layer of scoriaceous lava forming the outer part of the ridge being similar to that of the branch *c*, *d*, fig. 6. The continuity of the branch *c*, *d* with the main current (*a*, *b*), is such as to preclude the supposition of the slightest change of position in *c*, *d* since 1689, when it cascaded into the Cava Grande; and if there were no other section on Mount Etna to illustrate the capability of lava to form, when cooling on a steep slope, a dense and continuous layer of stone, such as would be termed trap in the ordinary language of geologists, this example in the Cava Grande would suffice.]

Structure, aspect, and inclination of the lavas of the great eruption of 1852–53.

From the Cava Grande we went by Milo to Zafarana, and observed at the former place some recent changes which the last great eruption of Etna, that of 1852, had

effected. One branch of the lava, flowing from the Val del Bove, had entered and filled up the bed of a torrent which passed by Milo, and the displaced waters have ever since been seeking a new channel. Just before our arrival (October 1857) they had undermined several houses in the village, and had excavated in a street through which we rode, a gulley 26 feet deep, displaying a section of alluvium of that depth, made up of rolled pebbles of various volcanic rocks. This evidence of torrential action at the height of 2136 French feet above the sea (the height of Milo as measured by S. v. WALTERSHAUSEN), is not without its bearing on questions hereafter to be discussed.

Zafarana, to which we next proceeded, is 1748 feet high. We found the country between it and Milo adorned with woods and vineyards, and furrowed by parallel ravines, reminding me of the barrancos of Madeira or the Canary Islands; but those of Etna are only incipient barrancos, the erosion of deep chasms by running water being checked, as we have seen, by the occasional filling up of water-courses by lavas and by the absorption of rain, by their porous crusts, and by loose volcanic sand showered down far and wide over the mountain.

At Zafarana we spent five days (October 26 to 30, 1857), making daily excursions into the Val del Bove and returning at night. Between the early dawn and 2 o'clock in the afternoon the sky was usually clear, and the sunshine bright, although there were occasionally clouds and even rain in the region of woods and vineyards below. As the mists ascended and enveloped us two or three hours before sunset, it was necessary to secure time for observation by mounting our mules before daybreak. I had visited Zafarana and the Val del Bove in 1828, and retained in my mind a vivid recollection of the leading geographical features of its grand scenery. I was therefore surprised and somewhat disappointed at the prodigious revolution which had taken place in the interval of twenty-nine years, a revolution caused entirely by the eruption of 1852–53, one of unusual magnitude, the violence of which does not seem to have been generally appreciated in Europe, because the destruction of human habitations was small. The lavas poured forth at that period are regarded by Dr. GIUSEPPE GEMMELLARO as having been perhaps the most voluminous of any that have ever been witnessed, or at any rate recorded, by man, with two exceptions, namely,—1st, that which overwhelmed so many villages and part of the city of Catania in 1669, flowing from Nicolosi to the sea; and, 2ndly, the lava-current of Mojo, supposed by some to have occurred in the year 396 before our era, but the date of which is, according to S. v. WALTERSHAUSEN, very uncertain, though its high antiquity is proved by the amount of subsequent fluviatile denudation which has made wide gaps in its massive current.

Narrative of the Eruption of 1852–53.—As I shall have occasion to allude repeatedly to the consolidation at high angles of this lava of 1852, I shall begin by giving some account of the eruption obtained from contemporaneous narratives of the event, or from conversations with eye-witnesses [and among others, the priest of the parish of Zafarana, Signor G. SCIUTO, who in 1858 kindly placed his diary at my disposal].

The three published accounts of the eruption, which were presented to me by their authors, are as follows:—

1st. Sunto del Giornale della eruzione dell' Etna del 1852, del Dottore GIUSEPPE GEMMELLARO. Catania 1853.

2ndly. Sull' eruzione presente dell' Etna di FRANCESCO TORNABENE, Professore di Botanica, &c. Napoli 1852. Parte 1^{a} e 2^{da}.

3rdly. Relazione della grandiosa eruzione Etnea della notte del 20 al 21 Agosto 1852, di GIUSEPPE ANTONIO MERCURIO. Palermo 1853.

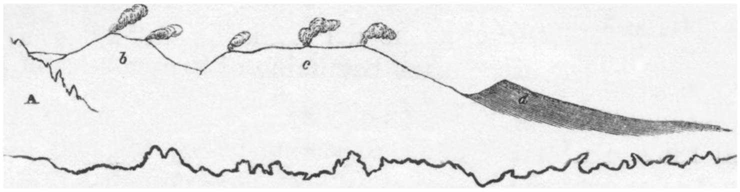
The first of these writers, Dr. GIUSEPPE GEMMELLARO, visited the Val del Bove during the continuance of the eruption, and I had frequent opportunities of profiting by his instructions and courteous explanations of what he saw.

The eruption began in the night of August 20, 1852, by the violent shaking of the central nucleus of Etna. Some travellers who were passing the Piano del Lago, on their way to the Casa Inglese, saw clouds of scoriæ thrown up from the highest crater. The Balzo di Trifoglietto, or the great precipice which forms the head of the Val del Bove, was rent so that in the course of that first night and the next day there were many openings, some accounts say seventeen, from one of which (No. 1 Map, Plate L.), larger than the rest, not far below the Torre del Filosofo, and between the Serra Giannicola Grande and the Serra Giannicola Piccola, scoriæ were ejected. According to some of the narratives, a small quantity of lava issued from this point.

[Dr. GIUSEPPE GEMMELLARO, in the small map appended to his valuable memoir above cited, has placed the upper mouth (No. 1 Map, Plate L.), as well as the two craters Nos. 2 and 3 *ib.*, to the south, instead of to the north of the Serra Giannicola Grande. Having with me in 1858 S. v. WALTERSHAUSEN'S map, which was not published when Dr. G. GEMMELLARO wrote, and my guide, ANGELO CARBONARO of Nicolosi, having accompanied travellers to the mountain on the night of the 21st of August, I was able to ascertain and lay down more exactly the site of these three points, though by no means with trigonometrical accuracy. The two cones and craters (2 and 3) lie north of the eastern extremity or base of the Serra Giannicola Grande. They were thrown up on the line of a great fissure, which opened the day after the eruption began, and are still very conspicuous objects at the head of the Val del Bove, as will be seen by the outline of their forms, given in two sketches in the next page, *b*, *c*, figs. 7 and 8, taken by me September 25, 1858, when, in consequence of heavy rain which had fallen the day before, the fumeroles were so numerous that the cones had almost the appearance of being still in eruption.

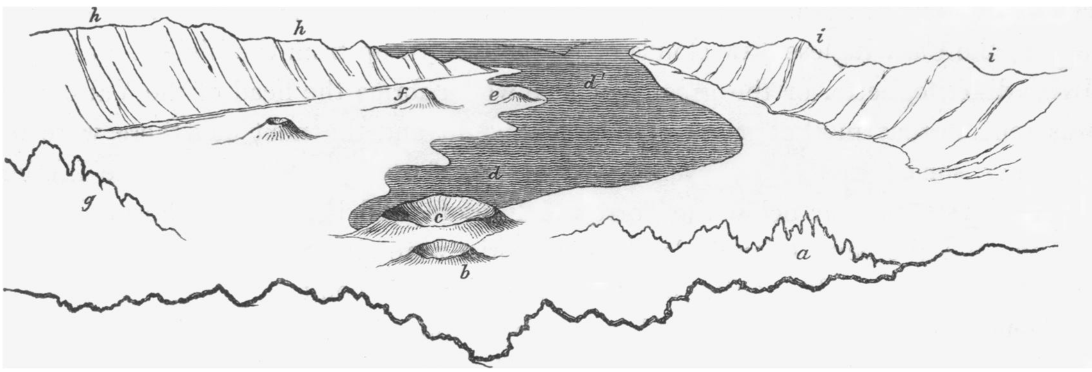
The bird's-eye view, fig. 8, obtained by looking down into the Val del Bove from the edge of the precipice, immediately below the Torre del Filosofo, will convey to the reader a tolerably correct idea of the position of the two craters, as seen from above, as also of the course of the lavas issuing from the base of the Centenario, and flowing towards Milo and Zafarana.

Fig. 7.—*Outline of the two cones of* 1852 *near the foot of Giannicola, as seen from the south.*



A. Lower part of Giannicola Grande.
b. Upper cone, No. 2 of Plate L.
c. Lower cone called Centenario, No. 3 of Plate L.
d. Commencement of the current of lava of 1852.

Fig. 8.—*Position of the two cones and of the lava of* 1852–53 *in the Val del Bove, as seen from above.*



a.	Part of Giannicola Grande.	*g.*	Giannicola Piccola.
b, c, d.	Same as in fig. 7.	*h, h.*	Concazze.
e.	Monte Finocchio Inferiore.	*i, i.*	Serra del Solfizio.]
f.	Rocca Musara.		

The inferior and largest of the two cones was named the Centenario, from a centenary fête which the Catanians were then celebrating. It vomited on the 21st of August, and for the sixteen succeeding days, incessant showers of sand, scoriæ and lapilli, with occasionally huge blocks of lava, building up a truncated cone, which became at length about 500 feet high on its eastern side, or the side towards the Val del Bove, and measured nearly 1000 feet diameter at its base. The first day (21st) the lava ran in eight hours to the Dagala dei Zappini (see Map, Plate L.), or about 4000 metres (two and a half English miles in a direct line, according to S. v. WALTERSHAUSEN'S 'Atlas'). On the 22nd it reached the Sciara di Femina Morta, or lava of 1284 (north-east of the Portella, Plate L., now covered by the lava of 1852), and then changing its direction from east to south, flowed towards Zafarana. On the 29th it came near Ballo, and on the 30th and 31st crossed the mouths of the valleys of S. Giacomo and Cava Secca, and continued for five days, scarcely advancing, but menacing Zafarana, till finally it halted within 144 Sicilian canne, or about a quarter of a mile of that town. The whole descent from the base of the Centenario to Zafarana may be about 3500 feet.

Another flood of lava, after passing near the hill called Finocchio Inferiore, approached the suburbs of Milo, while another ramification reached the huts designated Casale on the Map (Plate L.).

During the last days of August and the beginning of September, the 960 inhabitants of Zafarana had been kept in a state of continual terror. On the 2nd of September crowds of people came up from Catania, expecting to see the fiery deluge overwhelm that place. On the same day Dr. GIUSEPPE GEMMELLARO went up from Zafarana into the higher region of the Val del Bove, and obtained a near view of the eruption from the summit of Monte Finocchio Superiore. This hill rocked so violently to and fro with the motion caused by the neighbouring eruption, that his two companions (a guide and muleteer) experienced a sensation like that of sea-sickness. As they looked down from the hill, the whole Val del Bove seemed like a sea of fire, so wide was the expanse of molten matter. For miles they beheld ridges and deep hollows streaked with fire, and emitting a vivid light from numerous rents. Everywhere fragments of loose scoriform rocks were rolling down the steep slopes of the ridges, proving that large portions of the mass were still in motion. The lower cone, No. 3, Plate L., and *c*, figs. 7 and 8, was then between 300 and 400 feet high; explosions like those of artillery were unceasing, and scoriæ were cast up to great heights from the crater.

After a short lull, the intensity of the eruption was again renewed on the 4th of September and continued to the 7th, the column of vapour and sand rising to a vast height, and fresh lava issuing from the base of the new cone, No. 3, so as to overflow the current which had before taken the direction of the Portella di Calanna. The highest crater of Etna sympathized with this new outbreak, sending forth dense clouds of steam. Heavy rain fell on the 26th of September, and the guides of some travellers, who visited the summit of the mountain on that day, reported that the crater was freshly encrusted with a white muddy substance. [This encrustation still continues, October 1858, and has the appearance of a covering of snow at a distance.]

In October fresh lava flowed towards the valley of Calanna, and reaching the head of it, cascaded over the precipice more than 400 feet high, called the Salto della Giumenta. In its descent, says Dr. G. GEMMELLARO, it sounded as if metallic and glassy substances were being broken. It then flowed along the valley below the Salto. Dr. G. GEMMELLARO remarks, that though on this occasion he did not witness the phenomenon, yet at a former period, in 1819, he saw the lava cascade down the same height, and observed that after it had reached the base, and was creeping over the nearly level ground in the valley below, it did not seem to have lost any of its heat or fluidity by the descent.

From the beginning to the end of November and throughout December, the eruption went on, fresh lava running in various directions, and among others, along the base of the Serra del Solfizio and the hill called Zoccolaro, as also in a north-eastern direction towards Finocchio Inferiore, passing by Monte Caliato towards Milo. On the 21st of November, for the second time, lava precipitated itself over the lofty cliff before mentioned, called the Salto della Giumenta, and spreading over the fertile plain at its base,

consumed some of the richest land in Sicily. At the same time changes were observed in the form of the highest cone and crater of Etna. In November some of the lava which issued from below the cone called Centenario, was seen to run in a canal, or beneath an arched crust of solid scoriæ, where the surface had cooled and solidified.

The united breadth of the several lava-streams must have equalled two English miles, if measured in a north and south direction towards the eastern or lower limits of the Val del Bove, and their length was about six miles.

All January, February and March, 1853, intermittent explosions and ejections of scoriæ took place in the Val del Bove, and so late as the 26th of April the lava was still seen piling itself up, one stream over another, in the district of Zapinelli; nor was it till the 27th of May, 1853, more than nine months from the date of its commencement, that this memorable eruption ceased.

In regard to the temperature of the advancing lava, those currents, says Dr. MERCURIO, which were fluid (by which he evidently means those which were not greatly encumbered on their surface and sides with scoriæ and stony fragments), radiated so much heat, that trees caught fire and were consumed at the distance of several paces, whilst other currents, which he compares to a heap of moving stones, enveloped the fruit-trees with detached fragments along their borders, so that they were not even scorched. So slowly indeed was the heat conducted through the scoriaceous materials, that some of the trees actually vegetated anew, and burst forth a second time into flower (*ibid.*).

The depth of the lavas varied from 8 to 16 feet, but as successive streams were often piled one over another, they attained double and treble that thickness in some spots, and near the Portella they seemed to me to reach a height of 150 feet.

There can be little doubt that the various apertures (figs. 1, 2, and 3, Plate L.) which emitted lava in August 1852, each of which were formed successively at lower and lower levels, beginning at a great height and not far below the Torre del Filosofo, were all of them in connexion with the axis or highest crater of Etna; for this crater sent forth from time to time, from the commencement of the eruption to near its close, dense clouds of vapour, and occasionally red-hot scoriæ.

Burnt area.—A singular event of peculiar geological interest occurred some weeks after the 27th of May, when to all appearance the flowing of lava had entirely ceased, and when all the currents had become encrusted over with so firm a covering of scoriæ that the inhabitants could walk upon them with safety. Within a certain area (marked as the "burnt area" on the Map, Plate L.), six or seven hundred yards in diameter, and situated between Zafarana and Ballo, all the fruit-trees and vines were struck dead as if by lightning. The ground exhaled no hot gases, and the vegetation did not suffer in the space intervening between the parched-up area and the recent lava, which was only a few hundred yards distant. Dr. GIUSEPPE GEMMELLARO has suggested as the most natural explanation of this phenomenon, that the lava must gradually have made its way through underground passages, until coming beneath the fields alluded to, its heat dried up the roots of the plants. It is well known that vaults and tunnels abound

in many of the modern lavas of Etna, and such empty spaces must sometimes at a subsequent period be unavoidably filled from above with fused matter, which may then solidify under considerable pressure, giving rise to masses of crystalline rock, and offering a perplexing problem to a geologist if he should obtain a section of them without knowing the peculiar conditions under which they originated.

[My friend Mr. HARTUNG, during his late exploration of the Azores (July 1857), observed in Pico, one of the middle islands of that group, a subterranean passage of great length, traversing lava near the port of Cachorro, on the N.N.W. foot of the volcanic cone called the Pico, the highest in the Azores. The lava alluded to is covered with vineyards and orchards, and supports in one place a village, but not exactly where the underground caverns occur. Mr. HARTUNG entered this natural tunnel for several hundred yards, and found in the interior arched caves, some 20, others 30 feet high, occasionally lowering to 3 feet, and afterwards enlarging again. In one place, where the thickness of the roof was slighter than usual, the roots of some fig-trees were seen penetrating through rents, and hanging down into the cavern. Such subterranean cavities, situated only 170 feet above the sea-level, will certainly, says Mr. HARTUNG, be some day flooded by a lava-current from the Peak, in which case the vines and fruit-trees may escape unharmed in spots where the crust of scoriæ (so bad a conductor of heat) is dense, but the fig-trees, whose roots pierce into the caverns, will be killed.]

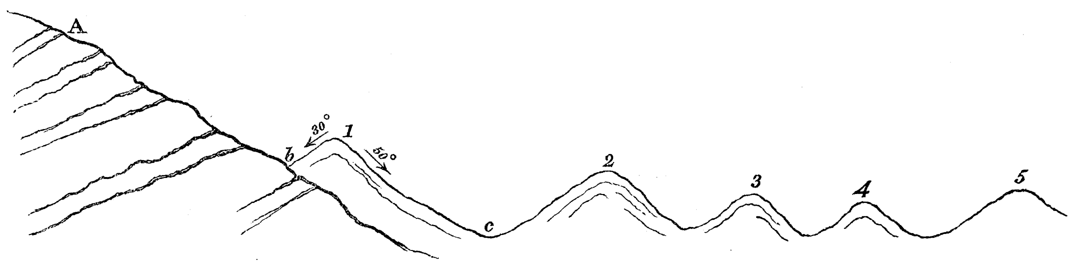
Aspect of the recent lava.—I shall next speak of the bedding and internal structure of the recent lavas above described, both those which have cooled on steep slopes and those which traverse gently inclined ground. It was in the northern suburb of Zafarana that we first encountered the great southern branch, which halted there, ending in a wall 30 feet high, and inclined at an angle of 37°. When I saw this sterile mass, composed externally of fragmentary materials, and listened to the stories told me of the manner in which it had crept slowly over the rich pastures and vineyards, utterly destroying them, together with several habitations, I was forcibly reminded of the like devastations and losses which I had witnessed only seven weeks before, as the effects of a cause as different in its nature as can well be conceived, the Alpine glacier of the valley of Zermatt, where an equally steep mound of rocky fragments, forming the frontal moraine, had been pushed forward by the slow but irresistible pressure of the advancing ice, over green meadows, gardens, and chalets, transforming them at once into a wilderness, irreclaimable for ages.

Passing along the borders of the lava, we soon came to a point where numerous fumeroles bore testimony to the heat still retained in the interior. The white vapours had no peculiar odour, seeming to consist entirely of steam, and we were told that they had been unusually copious for the last four or five days. My companion, Signor GAETANO, suggested that the heavy rains which had fallen a week before might be the cause, the water penetrating to the deeper and hotter parts of the lava, here of unusual thickness, and being thus converted into steam, an opinion which is in the highest degree probable. The scoriaceous surface, kept moist in some places by the warm steam, was verdant

with a moss, named for me by Professor TORNABENE, *Steelina pilifera.* I also found some other portions of the current whitened by a lichen called Stereocaulon, the same which I had seen on modern lava, both in the Canary Islands and on Vesuvius. The natural growth even of a cryptogamous vegetation, although restricted to limited areas, on lava of such recent date, is worthy of notice, and seems to give promise of an early fertility for the future. More than four centuries and a half have left the lava of 1381, at L'Ognina north of Catania, still black and barren, whereas the proprietors have already planted certain tracts of this new current of 1852–53 with broom, which is growing most freely.

Between Zafarana and the lower entrance of the valley of Calanna, called the Portella, we had occasion to pass and repass daily certain portions of the fresh lava, the surface of which displays a series of longitudinal ridges and furrows of extraordinary height and depth, running nearly north and south (N.N.W. and S.S.E.). According to a rough estimate, I found that the crests of the ridges rose from 30 to 70 feet above the bottom of the intervening and parallel depressions, and they varied in number from three to five within the same area, when crossed from east to west. The course of the ridges is similar

Fig. 9.—*Gigantic parallel ridges in the lava of* 1852, *near the Portella of Calanna.*



A. Older inclined lavas and tuffs of Sciuricosimo.
Nos. 1 to 5. Parallel ridges running from N.N.W. to S.S.E., and here supposed to be intersected transversely.

in direction to that of the lava-current. The letter A, fig. 9, represents the escarpment of ancient rocks, called Sciuricosimo (see Map, Plate L.). The ridge No. 1 has a vertical height of 25 feet on its western side, where it slopes at an angle of 30°, and on its eastern side, where in the steep part the slope is 50°, the height above *c* is no less than 70 feet. The ridges (Nos. 2, 3, and 4) are respectively 40, 30, and 25 feet above the intervening depressions. Nearer the Portella, we find some of the flanks of these ridges inclined at 60°; and at certain points, where there had been landslips, they were perpendicular and even overhanging. In such cases, the arrangement consists of, first, one or more irregular outer layers of scoriaceous lava, 2 or 3 feet thick in all, and then, 2ndly, beneath or within that outer crust, several concentric layers of compact rock, each from 6 to 10 inches thick, of the usual Etnean type, exhibiting crystals of felspar in a grey base, with olivine and titaniferous iron, and a few crystals of augite. These interior stony layers we observed in one case inclined at an angle of more than 70°.

Passing up from the Portella (see Map, Plate L.), we came to the hill of Calanna,

between which and the hill of Zoccolaro occurs the great precipice, more than 400 feet high, before mentioned, called the Salto della Giumenta, over which the recent lava twice cascaded, in 1852–53, as already stated, p. 723.

In 1828, I had seen the beautiful valley of Calanna covered with verdant pastures, and bounded by heights adorned with forest trees, so that it formed a blooming portal leading up to the wilder scenery of the more elevated Val del Bove. Now, the once fertile plain was black and desolate, buried under a flood of slaggy lava; and when we ascended from Calanna to the upper platform, I missed still more the picturesque contrast of woodland full of old forest trees by the side of dark strips of sterile scoriæ. The whole region had now become one great monotonous desert, without any relief to the eye except on a clear day, when the lofty precipices forming the head of the magnificent amphitheatre, and crowned with the highest cone of Etna, with its banner of fleecy clouds, were full in sight. The points of highest geological interest, formerly accessible by mules, are now only to be reached on foot by a tedious and circuitous route. There are no longer any cattle in the valley, nothing to justify its original name, scarcely a living creature to be seen for days, though a few goats are still driven up to browse on some shrubby knolls which have escaped the general devastation; and now and then the footprints of a wolf on the sands made us wonder that their prey had not yet wholly failed them.

Aided by an experienced guide, Signor G. G. Gemmellaro and I crossed a part of this new lava-field in as straight a line as we could follow, from a point northwards of the hill of Calànna to the rock called Finocchio Inferiore in the great map of S. von Waltershausen. There was as yet no footpath, not even a goat having passed that way. We found the black scoriaceous crust bent into exceedingly sharp, longitudinal ridges, separated by narrow interspaces, from 20 to 40 feet deep, the sides of each ridge sloping at angles of from 20° to 40°, but seeming at some points to be absolutely vertical. On the crests of each ridge were fragments of scoriform lava, sometimes tabular, and sticking up edgeways, like sheets of broken ice on a Canadian river, where an obstruction or "jam" has stopped the floating masses. More frequently the projecting portions of the superficial crust assumed the forms of gigantic madrepores, or of various animals, such as dogs and deer, or still oftener the heads of elks, with branching horns. The surface often resembled, in all but colour, the descriptions given of coral reefs; and at one moment, when my foot slipped, I had an opportunity of knowing that the stony asperities could tear the flesh of my hands as readily as real corals. The stones on the top and sides of most of the ridges were so loose, that no sooner was one of them set a-rolling, than it started a number of others, until a continuous avalanche poured down into the trough below; but as we had to zigzag our way up each steep ascent, there was little danger of one of us being just under his companion when the torrent came down. Now and then our direct march was arrested by a ridge, rendered impassable by its steepness or the incoherence of the stony fragments forming its crust, which obliged us to make a long circuit, often with our backs turned towards our goal, the hill of Finoc-

chio. The manner in which detached blocks of various shapes and sizes were occasionally poised one upon another, on very narrow ridges, made us marvel that high winds had not blown them down. I climbed up to some of them, to ascertain that they were not soldered on to the mass of scoriæ below; but I found them free to move, and only holding on by the slight inequalities of their surface. At no point could I discover fissures or openings in the scoriaceous crust out of which melted matter might have escaped in a stream so as to fill up the trough below; but pieces of scoriæ had often rolled down in great numbers into the troughs.

At length gaining Finocchio, we found it standing like a rocky islet, submerged up to its middle in lavas of different ages, and with the fresh current of 1852 near its base. The relief afforded to the eye by this oasis was so great, that, although the day was cloudy, the green turf, enlivened by the flowers of a yellow ragwort, looked dazzling by contrast with the dark surrounding desert, and the autumnal crocus (*Colchicum autumnale*), also in full bloom, seemed more than ever beautiful. Returning to the spot where we had left our mules, we at length rode back to Zafarana, over another part of the new lava, where hundreds of fumeroles rose in dense white columns of steam, each of them quite perpendicular, for there was not a breath of wind; and conspicuous from having usually a background of dark lava to show off their graceful forms; so that we could no longer complain, as in our morning's ride, of the featureless monotony of the scene.

The problem ever present to our minds, during the whole of this excursion, was the cause of the curvature of the lava into a series of gigantic wrinkles. In what manner are we to account for these longitudinal and nearly parallel, anticlinal and synclinal ridges and troughs? It is well known that every stream of lava, as soon as its surface and sides have congealed, is encrusted over with a covering of scoriæ and stony fragments, so that it may be said to run in a tunnel, the roof of which is in most cases a flattened arch. The supply of liquid from the source or vent being irregular and intermittent, the current now and then halts for a while, sometimes for hours, days, or weeks, during which time a solid terminal wall is often produced, and one stony layer after another may then be formed gradually within the outer crust by the lava congealing on the sides and roof of the arched tunnel. Such concentric, internal layers having consolidated slowly and under pressure, will often acquire a compact and crystalline texture. But when fresh supplies of hot lava descend from the source, that portion of the current which still remains fluid or viscous being reinforced, may burst through the terminal crust, and the onward progress of the lava recommences. We have already seen, p. 724, that the lava of November 1852 was actually observed, near the foot of the Centenario, to flow in an arched channel, and there were doubtless many other similar lava-ducts having a parallel direction, or running longitudinally in reference to the stream.

[Mr. Scrope has suggested to me, that when fresh molten matter penetrates into such subterranean ducts, they may, by hydrostatic pressure, cause the superincumbent mass to crack and swell up into steeper arches than those originally produced; and I think it probable that such may be the true explanation of the phenomenon, though

before I had witnessed the eruption of Vesuvius in 1858, and had seen a ridge in the act of forming, I speculated on the possibility of the lava of 1852 having been partially forced into its present shape by lateral pressure, caused by the successive flows of lava having been piled one over the other, while the interior of some of the currents first poured out was still viscous or even liquid. The great weight and thickness of the new flows might, I imagined, have given rise, by hydrostatic pressure, to effects like those witnessed where certain railway embankments have been thrown across marshes and peat mosses. In such cases, it is frequently found that as fast as new matter is cast upon them the mounds sink down bodily, while on one or both sides the surface of the bog or morass swells up in one or more parallel undulations. I also referred to the analogous effects of downward pressure, to which my attention had been directed by Dr. GOULD in 1852 at Boston in the United States, where a load of sand and stones, upwards of 900,000 cubic feet in volume, had been thrown into part of an estuary only dry at low water in order to convert it permanently into land. In consequence of the pressure, the adjoining bottom of the estuary, supporting a dense growth of salt-water plants, and previously only just visible at low tide, was pushed gradually upward, in the course of many months, so as to project 5 or 6 feet above high-water mark. The upraised mass was bent into five or six anticlinal folds, and the upper layer of turf having burst open along the crests of the ridges, exposed to view an underlying layer of mud full of recent marine shells*. But I abandoned this explanation of the origin of the Etnean ridges after I had seen similar, though much smaller ones, produced on the flanks of Vesuvius in the manner about to be described.

When I visited that volcano in September 1858, I found that the eruption of the preceding spring had not wholly ceased. Intermittent jets of vapour, illumined by the hot lava of the crater below, were still issuing from the summit, while two minor cones at the western foot of the principal cone, and just below the Observatory, were pouring out continually small rills of lava unaccompanied by any evolution of gases. Some of these rills ran very rapidly near their sources, but when they reached the base of the cone proceeded with extreme slowness. Here I watched the progress of one of them, about 8 feet high, having the form of a steep-sided and narrow ridge, its sharp crest crowned with just such irregular and grotesque-shaped fragments of rock as are seen on the new lavas of the Val del Bove. Its motion was onwards in a straight line, but was only appreciable by great attention. The change of position of the protruding fragments on the crest was only verified by observing their altered relation to other fixed and motionless points of lava just beyond. Viewed in the daytime, the advancing ridge was black, but now and then one of the steep sides was seen to swell out as if composed of viscous matter, and then to crack, disclosing a glowing and white heat within. This opening was soon followed by an avalanche of fragments, black on one side and red-hot on the other, rolling down with a clattering sound to the bottom of the slope. Instead of an escape of lava and levelling up of the ground on one side, or any

* See LYELL'S 'Manual of Geology,' p. 136, 5th edit.

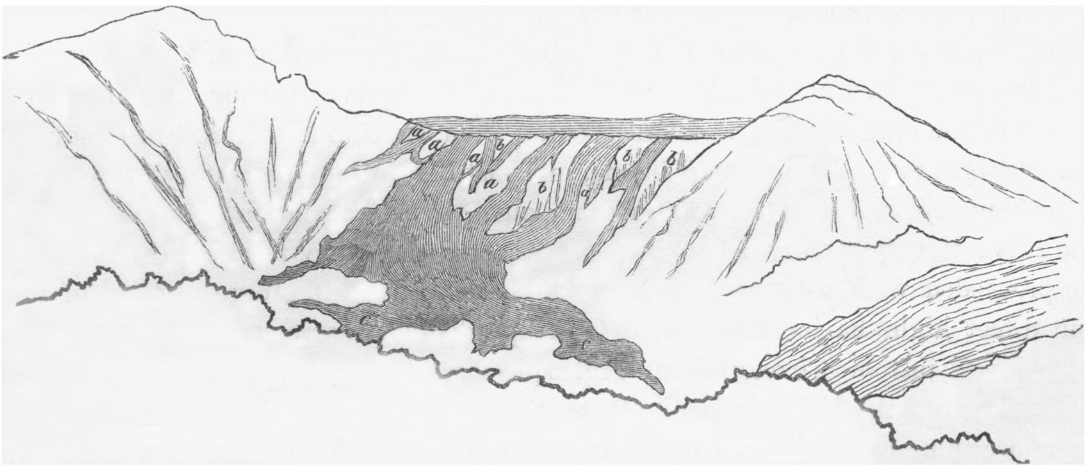
undermining of the ridge, this last retained its full height with its crest or "riggin" unimpaired and its flank even steeper than before. At the same time the most advanced portion of the fluid lava was stealing on beneath a heap of scoriæ which had rolled down from the front or lowest extremity of the ridge, so that the manner in which the foremost part grew in height could not easily be seen.

But although the weight or hydrostatic pressure of fresh loads of melted matter piled upon a current not yet consolidated may rarely if ever give rise to lateral ridges in the manner first suggested at p. 729, it may nevertheless and doubtless does often happen, that this same pressure acts with great force on different parts of the sides and roof of one and the same tunnel, uplifting a viscous or semi-fluid mass, and remodelling the form of the whole current.]∞

Inclined lava of 1852–53 *at the Salto della Giumenta, or head of the Valley of Calanna.*

We have seen that in the course of the eruption of 1852 above described, the lava descended more than once over the great precipice, above 400 feet high, called the "Salto della Giumenta," which intervenes between the hills of Calanna and Zoccolaro (see Map, Plate L.). The width of the summit of this declivity is, according to S. von Waltershausen's Map, about 200 English feet, but the space over which the lava fell, according to a rough estimate which I made by pacing it, is considerably less. The annexed drawing will give a general idea of the appearance of the dark lava encrusting the

Fig. 10.—*Lava of* 1852 *cascading down the precipice called Salto della Giumenta.*



a. Lava of 1819. *b.* Precipitous outliers of old rock surrounded by recent lava.
c, c. Lava on the level ground in the Valley of Calanna.

steep slope, the spots faintly shaded with vertical lines consisting of ancient rocks, chiefly composed of felspar and hornblende, assuming on decomposition a brown ferruginous colour, and protruding in masses with almost perpendicular sides like the rock in the middle of the Falls of Schaffhausen, or like Goat Island in the Falls of Niagara. Some greyish stripes marked *a* and left white in the drawing represent the lava of 1819, which also went down this same precipice, but which has been since for the most part covered

by the lava of 1852–53. Fortunately at several points the superficial scoriæ, about 3 feet in thickness, has been washed off from both of these lavas by the rain. In the case of that of 1852, we see exposed to view the surface of an underlying stony layer, cellular in part, or somewhat vesicular, but continuous, and containing crystals of felspar and some imperfect ones of augite, with deep-green olivine and great abundance of titaniferous iron. From the stony character of the surface of this bed immediately under the scoriaceous crust, there can be no doubt that 6 or 8 inches lower down it would present a compact texture. The surface of the continuous stony mass alluded to is inclined at angles of 35°, 40°, and 45°, and in one spot at 49°, if not 50°, an angle which my companion obtained with the clinometer, but not without some risk of slipping and being precipitated to the bottom of the precipice. What we had seen in the Cava Grande (p. 717) had prepared us to expect the existence of such a tabular layer of stone beneath the external scoriæ*.

It will be seen by the sketch (fig. 10) that part of the lava of 1852–53, after going down the precipice, continued (at *c*, *c*) its course along the bottom of the nearly level valley, where the slope is not more than 5° or 6°. Here the general depth of the modern current is evidently greater than on the slope, amounting perhaps to 8 feet.

At one point on the declivity of the "Salto" we examined a portion of the lava of 1819, where it had a width of 16 feet, and where the remainder or lateral prolongation of the same was hidden by the lava of 1852. The older current passed under the newer with a corresponding inclination of more than 40°. In such cases a vertical section would exhibit several parallel beds, one over the other, consisting alternately of scoriaceous and stony lava. We estimated the thickness of the lava of 1852–53, on some parts of the declivity (judging by its lateral walls), at about 5½ feet, of which 2 or 2½ may be composed of stony matter. One of the narrowest streams or ramifications was 70 feet wide; so that if the stony portion was seen in a transverse section, say 2 feet thick, it would appear as a thin sheet of matter, the horizontal being to the vertical extension as 30 to 1. Even if the solid layer be twice as thick, the width remaining the same, it would still constitute a tabular mass, having nearly even planes of stratification, and these planes being parallel to the upper and lower scoriæ.

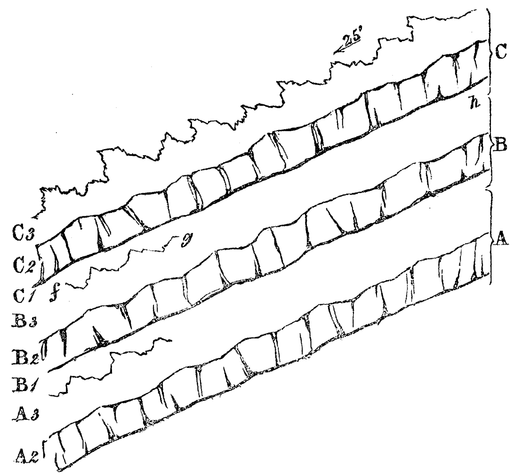
Some geologists imagine that the general absence in the walls of the Val del Bove of extremely irregular surfaces similar to those of recent lava-currents, or exhibiting ridges like those of figs. 6 and 9, pages 718 and 726, furnishes an argument against the analogy of ancient and modern volcanic formations. But there are many reasons why such uneven lines of separation should be rare and exceptional on steep slopes, and should even be obliterated where they have once existed.

In the first place, if the older lavas alluded to were formed, as I believe them to have been, at high inclinations, their surfaces could not originally be very uneven, as we learn from the examples of this "Salto" at Calanna and of the Cava Grande, p. 15, and

* [After re-examining the "Salto" in 1858, I have little to add to the above statement. I myself found a dip of 48° in the exterior of the cascading lava of 1852, not far from the north-east side, or Hill of Calanna.]

others hereafter to be cited. 2ndly. The bottom scoriæ of the newer current is usually so dovetailed into the top scoriæ of the older which it overflows, and so amalgamated with it, that the line of junction, instead of being marked, will usually be obliterated. Let the uppermost line in fig. 11 represent the uneven surface of the most recent of a

Fig. 11.—*Obliteration of the junction-lines of successive lava-streams.*



series of lavas which have been piled one over the other on a slope of 25°. The lava C, the newest of the whole, consists of three parts, namely, C 1 the lower scoriæ, C 2 the central stony portion, and C 3 the upper scoriæ. It will be seen that the bed last mentioned (C 3), although extremely irregular at top, is much less so at bottom, where it passes somewhat suddenly into the stony layer C 2; and again, the latter passes still more abruptly from the solid to the scoriaceous form into C 1, in which the upper plane of stratification is tolerably even. As this lower bed of scoriæ (C 1) had to adapt itself to all the superficial inequalities of the antecedent lava B 3, it might have been expected to afford a junction-line at its base as uneven as the dotted line f, g; but no such line occurs in nature, because, in the first place, the two lavas B and C following each other next in order of time are usually of similar composition, and the bottom scoriæ of the newer blends into a uniform mass with the upper scoriæ of the older current, so that we cannot discover (as between g, h) where one ends and the other begins. If the heat of C 1 be sufficient to reduce some part of B 3 to a state of fusion or semifusion, it will be still more difficult to tell which is which. If the overflowing lava moves rapidly, it can scarcely fail to exert a certain amount of friction on the bottom, so as to abrade and level down such asperities as occur on the top of C 3, and which originally belonged to the surface of B 3. But if the lava moves slowly, as it sometimes does even down a steep cone, then another levelling operation comes into play, one which I witnessed during the eruption of Vesuvius, on October 14, 1857, in the Atrio del Cavallo. The lava had been flowing for more than two days, and had gone down from the margin of the great crater to its base, and was there proceeding at a leisurely pace over more even ground. So slight was the motion, that the mass seemed stationary, till after watching it for a

few minutes, we saw fragments detach themselves and roll down the steep-fronted terminal wall, and not stop till they were far in advance of the main body of the current. Such blocks would soon level up any depression that might exist in the superficial crust of an older lava, and would also tend to assimilate in character the component parts of the upper and lower scoriæ. Passages of this kind of the top of one lava-stream into the similarly constituted base of that next above it, are conspicuous not only in the structure of Etna, but in certain sets of lavas in Madeira and in the island of Palma in the Canaries, where the flows of melted matter seem to have followed each other at intervals of time too brief to allow of the production of soils by decomposition, and where consequently no burnt clays of a red colour mark the boundary lines between successive lavas. If, however, a great interval occurs before a fresh current takes the same direction, other causes may come into play to obliterate the superficial roughness of the exterior of an older stream. Thus, for example, showers of comminuted scoriæ drifted by the wind, spreading usually over wider areas than lavas, may fill up hollows; floods of water charged with sand may do the same; the action of the sun, rain, frost, and vegetation causing the disintegration of rocks, may combine to make the successive planes of stratification more even and parallel than at first, though it is true that in most of these cases the red or burnt tuffs would betray the lines of separation.

[*Highly inclined stony lava of modern date in the Cava Secca near Zafarana.*

As the fact of lava being converted into a continuous stony mass when it cools on steep slopes will perhaps be said, even if admitted, to be the exception, it will be desirable to multiply examples in order to show that it is in truth the rule. By reference to S. von Waltershausen's Map, Plate L., the reader will see the position of a narrow valley, about 300 feet or more deep, called the Cava Secca, about a mile W.N.W. of Zafarana. The lavas, scoriæ, and tuffs intersected by this ravine, are many of them among the oldest exposed to view on Mount Etna, and are inclined to the S.E., as are those in the neighbouring valley of S. Giacomo. Near the lower termination of the ravine, at the point *a* on the annexed Map, Plate L., on a steep slope above the right bank of the torrent, a comparatively modern lava is seen, which has descended, subsequently to the excavation of the whole valley, so as to overflow the edges of the older strata, which are inclined in quite a different direction. The side wall of this modern current has been undermined and partially removed by aqueous erosion, just as it has in the case of the lava of 1689 in the Cava Grande before described, p. 717. The section here also shows a dip of 35° N.E., both for the crust of scoriæ $2\frac{1}{2}$ feet thick, and for the central stony layer of about the same thickness. The lower scoriæ are also exposed to view for a depth of 3 feet, and sometimes more. The stony stratum is somewhat porous, yet its specific gravity is no less than 2·554 when first plunged into water, or before any air-bubbles have had time to escape from its inner cells. Many crystals of felspar and a small quantity of olivine are visible in the rock. I observed this modern inclined lava on the right side of the steep mule-path which leads up from the Cava Secca to a plat-

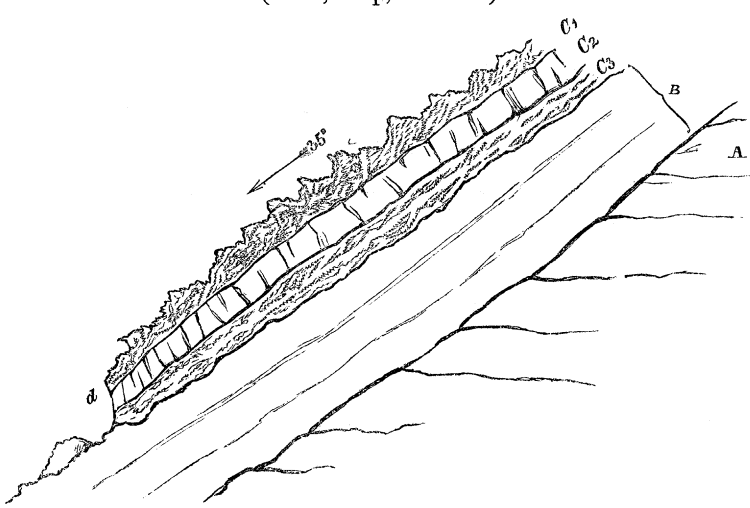
form, by which one may ascend to the flanks and summit of Zoccolaro. The best section occurs at the height of about 60 feet above the bottom of the ravine, opposite a dike which traverses the older lavas on the left or north side of the Cava Secca. The inclination of the lava augments higher up the slope to 40°, and the stony layer decreases to a thickness of 6 inches; but this occurs very near the edge, and it is probably thicker in the middle of the current, which is at least 130 feet wide. At the same place the lower scoriæ are 3 feet thick, and are seen to rest on a red, burnt tuff. On approaching the top of the pass, there is no longer any lateral section of the inclined lava to be seen, for it is there overflowed for a considerable space by a more modern current, viz. that of 1792, the course of which is laid down in S. von Waltershausen's map (see Plate XLIX.).

The Cava Secca, therefore, affords us an instance of a lava having a central continuous layer as compact as are most of the beds of older date in the Val del Bove, and that layer is inclined at angles of 26°, 30°, and 40°, and is partially covered by a newer lava (that of 1792) in one part of its course, where both currents slope at an angle of 26°.

Steeply inclined compact lava of modern date below the Cisterna (*b*, Map, Plate L.).

The next remarkable instance of a steeply inclined continuous sheet of compact modern lava to which I shall advert, occurs at a point 5000 feet higher than that last mentioned, or near the top of the great precipice at the head of the Val del Bove, not far below the Cisterna. Its lower termination may be seen just above that upper part of the Serra Giannicola to which S. von Waltershausen has given the name of Teatro Piccolo (at the point *b*, Map, Plate L.). Its dip is between 30° and 35° East, and in some parts 38°;

Fig. 12.—*Modern inclined lava between the Cisterna and the Teatro Piccolo, or upper part of Giannicola* (see *b*, Map, Plate L.).



its upper crust of scoriæ (C 1, fig. 12) is about 5 feet, the central stony mass (C 2) 7 feet, and the lower scoriæ (C 3) 7 feet thick. The whole is finely exposed to view, the rain and melted snow having washed away the subjacent scoriæ from both sides of the current,

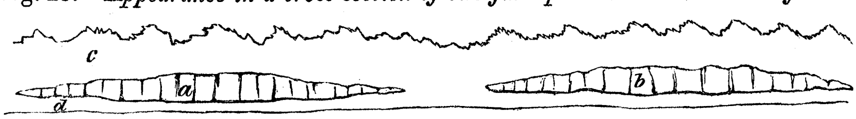
which is 50 feet broad, so as to undermine the incumbent stony bed, and cause a vertical, or here and there a more than vertical section, for the stony layer occasionally overhangs 4 or 5 feet. The lower scoriæ are divided into distinct strata, and contain masses of ropy lava and volcanic bombs. The solid bed (C 2) is usually very compact, and although in parts vesicular, is on the whole more stony than the average of the older lavas of the Val del Bove, or of the precipice called Balzo del Trifoglietto. The rock consists, like so many of the modern lavas of Etna, of a dark-coloured base, in which are many crystals of felspar and some of olivine. Its specific gravity is 2·785.

At the lower end (*d*), where a transverse section is obtained in consequence of fragments of the terminal crust having fallen down, we find the whole thickness of the mass reduced to 8 feet, the top scoriæ (C 1) being from 3 to 4 feet thick, below which is the usual stony bed, here of a bluish colour, from 1 to 2 feet thick, and then the lower scoriæ. At the same point (*d*), I observed from below the current C another antecedent lava (B) with a powerful upper crust of scoriæ emerging with a like steep dip. There may possibly be some other conformably inclined modern lavas between B and A, which last represents the nearly horizontal older rocks, which in this part of the precipice we know from numerous sections dip gently to the south and south-east.

For several hundred yards down the face of the precipice I ascertained the continuity of the current (C, fig. 12), but at one point I found that the entire mass had been rent, probably by an earthquake, in a direction at right angles to the course of the lava, so that an open fissure 2 feet or more wide now discloses its internal structure, showing that the stony sheet of rock in the centre is persistent in a transverse as well as in a longitudinal direction, affording us an opportunity of determining that it does not, like some narrow lava-streams on a steep slope, sink in the middle, the centre being lower than the sides, as if the lava had run out and caused the crust to fall in. The open rent may imply the sliding down of a portion of the mass at the time of the fracture; indeed I could not look at the dip of this massive current (C), especially its central compact layer, without wondering that the whole has not, during the reiterated shocks to which this part of the mountain is subject, been hurled down into the valley below.]

Many geologists, on beholding from a distance several of these narrow strings or rills of molten matter congealed on the surface of a great talus of sand and scoriæ like that below the Cisterna, may imagine that a cross section could never present to them any appearances analogous to those which we witness in the Val del Bove or in the Atrio del

Fig. 13.—*Appearance in a cross section of two juxtaposed narrow streams of lava.*



Cavallo. But we must remember that the lava above described is 50 feet wide, and if the solid layer be $6\frac{1}{2}$ feet thick, it would be like *a* in the accompanying diagram (fig. 13); and if another similar current should flow down by its side, so that the outer and lateral

scoriæ of each should touch and join in the middle of the section, then *b* would seem to be a prolongation of *a* with merely one of those slight breaks or thinnings out and resumptions of beds with which we are familiar.

I may observe in concluding this subject, that if there be cases (though I did not happen to see one on Mount Etna) where the melted matter has run out from the interior of a stream of lava which has descended a steep slope, so as to cause the superficial crust, together with the solid central layer, to fall and cover in separate pieces the floor of the arched tunnel, this fact would not favour the notion of those who question the analogy of ancient and modern formations in volcanic mountains. The result of the collapse would be simply this, that a stratum of fragmentary and scoriaceous materials of unusual thickness would be seen in the area of the downfall.

Highly inclined modern lava near the Montagnuola.

In the Map of the Val del Bove (Plate L.), the position of the cone called the Montagnuola will be seen. The summit of the steep escarpment immediately below and to the east of it is called the Schiena del Asino. In order to pass from the Val del Bove to the upper region of Etna, we ascended this precipice, more than 2000 feet high, observing the edges of a vast series of ancient volcanic rocks, some crystalline but mostly fragmentary, which dipped to the south-west or inwards, and away from the Val del Bove. At some period since the formation of this great escarpment, and consequently since the origin of the Val del Bove (of which it forms the southern boundary), a lava of unknown date, but evidently from its external characters not very ancient, has poured over the brow or upper margin of the cliff, and running down the slope has covered the outcropping edges of the older lavas and scoriæ. As so often happens where the slope is great, the interior of this current is laid open at its side by the waste, from atmospheric causes, of its scoriaceous crust. Its thickness is 20 feet where it commences its descent, on ground inclined at an angle of 30°, and where the declivity augments to about 35°, the thickness diminishes to about 15 feet.

Here as elsewhere, there is an upper and a lower scoriaceous mass, but somewhat more than half of the whole consists of stony lava, more or less vesicular. We have in this case therefore a solid layer, varying from 8 to more than 10 feet in depth, the thickest seen by us at so high an angle. The current, after flowing down a few hundred yards, seems to have been exhausted, and is for the last few yards of its course broken up into detached and more or less scoriaceous fragments.

Leaving the Val del Bove, we then examined some sections afforded by the channels of torrents, dry at the end of October, which here and there have eaten into the flank of the great cone of Etna, between the Schiena del Asino and the town of Nicolosi. We had not gone far from the "Casa del Vescovo" (sometimes called the Casa delle Nevi), before we saw in one of the watercourses alluded to, a lava dipping at various angles between 26° and 29°, and having a thickness of between 5 and 6 feet. As usual, there was a thin stony layer forming the core or central part. A mile or more further down we

found a dry gulley, evidently excavated by water, 30 feet deep, in which many lavas were intersected having irregular dips, as if, when they flowed into this hollow, the shape of the ground had been repeatedly altered by showers of sand and lapilli, and sometimes by aqueous erosion. Occasionally the angle of dip amounted to 20° or even 28°. The stony beds scarcely ever exceeded $2\frac{1}{2}$ feet in thickness, but were often very compact. All these are of unknown date, but they cannot be of high antiquity, since on this southern slope, where eruptions have been so frequent in historical times, they constitute the outermost integuments of Etna.

If it did not appear to me superfluous, I could enumerate other instances of stony layers which have congealed on slopes of from 10° to 15°, and even higher angles in other parts of the great volcano; but the cases already cited will establish, as a rule, the fact that lava is capable of solidifying and forming stony and continuous layers on slopes even steeper than those on which loose cinders and lapilli can settle. These last may accumulate at an angle of 40°, or even more, for I have seen scoriæ settle on a slope of 42° before my eyes in the recent cone built up in October and November 1857, within the crater of Vesuvius; but in this instance the lava was in a state of semi-fusion when it fell, and the separate fragments may have been soldered together.

Recapitulation.

I will now briefly sum up some of the leading conclusions to which we have been led by the facts described in the foregoing pages, or first part of this memoir.

1st. Lavas which consolidate on steep slopes at angles varying from 15° to 40°, do not consist of a confused mass of scoriæ or of fragmentary matter, but of distinct parts, namely, an upper and lower mass of scoriæ, with an intermediate stony layer.

2ndly. The core or central portion forms a tabular and continuous sheet of compact stone parallel to the overlying and underlying scoriaceous formations, and usually passing somewhat abruptly into them.

3rdly. The lower mass of scoriæ, where the slope is very steep, is more commonly divided into distinct strata than the upper crust.

4thly. There is usually a greater evenness and parallelism of the beds where lavas have congealed at high angles, than where they have consolidated on more gently sloping ground.

5thly. When successive streams of lava have flowed one over the other down steep slopes, the line of junction between the lower scoriæ of one current and the upper crust of the antecedent one is often obliterated.

PART II.

ON THE STRUCTURE AND POSITION OF THE OLDER VOLCANIC ROCKS OF MOUNT ETNA, AS SEEN IN THE VAL DEL BOVE, AND ON THE PROOFS OF A DOUBLE AXIS OF ERUPTION.

It is now time to inquire into the structure of what has been called the nucleus of Etna, sections of which are seen in the cliffs which wall in the Val del Bove on three sides. How far do the mineral characters, and inclination of the volcanic masses composing that nucleus, imply that they were erupted from one or more central craters, and arranged from the first in a conical form; or how far can it be maintained, on the contrary, that they were originally horizontal, or nearly so, and were then, as the advocates of the Elevation-crater hypothesis contend, brought into their present position by movements of upheaval?

Proofs of a double axis.—Cones of Trifoglietto and of Mongibello.

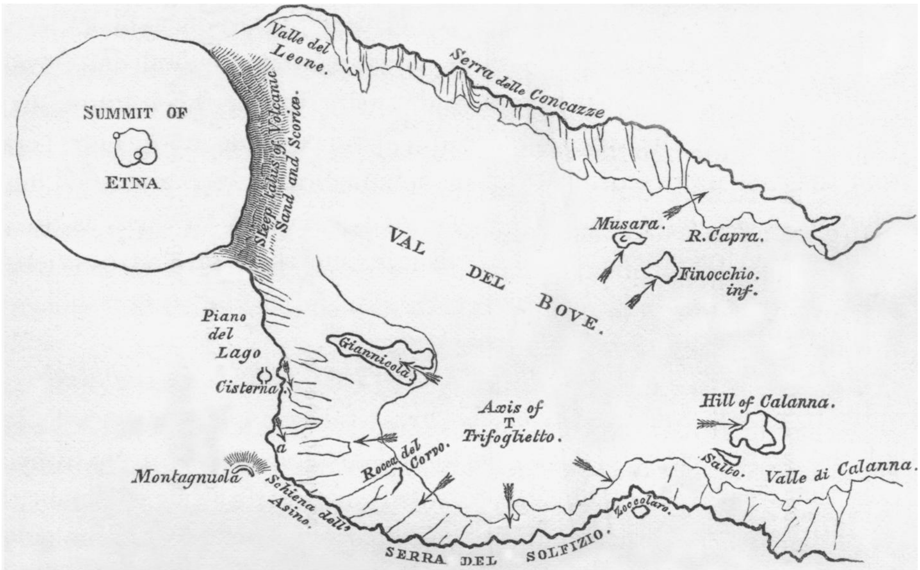
I was aware, from my examination of the great valley on the eastern flank of Etna in 1828, that the beds seen both in the north and south escarpment dip away from the valley; but in that year I had not time to satisfy myself in what direction they were inclined in the lofty western escarpment, at the upper end of the great amphitheatre and below the highest part of Etna. I had observed, as HOFFMANN and others did after me, that there were large amorphous rocks at the foot of the Serra Giannicola in which no stratification is discernible, and which consist in great part of innumerable dikes, some of very large dimensions, penetrating tuffs and agglomerates, the latter so altered by the intrusive matter, that the only divisional planes to be seen are such as are parallel to the walls of the dikes. But on this occasion (October 1857), I found masses of considerable thickness, not far above the base of the Serra Giannicola, distinctly stratified. The rocks alluded to consist of alternations of trachyte and trachytic agglomerate in beds of variable thickness, dipping at angles of from 20° to 28° to the north-west, or towards the central axis of Etna, that axis being about three miles distant in a horizontal direction.

My companion, Signor G. G. GEMMELLARO, had become well acquainted during previous visits with this fact of a northerly dip in the Giannicola beds, which was, I believe, first discovered by Baron S. VON WALTERSHAUSEN; for I learnt on my return to England that it had long been known to him, although not as yet published in his 'Atlas,' the fifth and sixth Numbers of which had not appeared in 1857. I was the more struck with the discovery, from having on the same day observed that the beds in the lower half of Zoccolaro (see Map, fig. 14), which are directly opposite, or about two miles to the S.E., and very similar in colour and mineral composition, dip in a contrary direction, or to the S.E., while those at the foot of the Montagnuola, as well as those between it and the Giannicola, are inclined to the S.W.

I knew, from what I had seen of Etna in 1828, that in the outlying and isolated rocks

of Finocchio and Musara near the middle and northern side of the Val del Bove, and in those of the northern escarpment, the dips were north-easterly, and I now therefore came to the conclusion that there must have been an ancient centre of eruption

Fig. 14.—*Map of the Val del Bove, showing the dip of the beds away from the axis of Trifoglietto.*



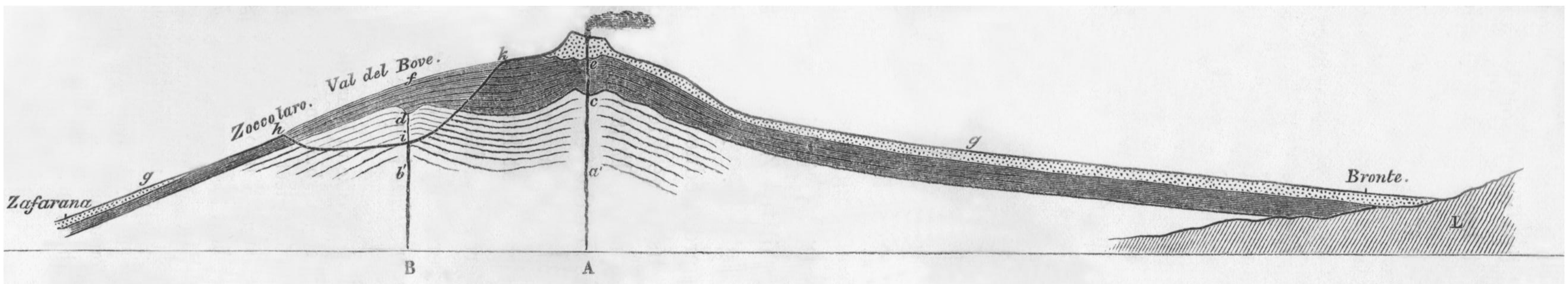
in that part of the Val del Bove called the Piano di Trifoglietto, at a point about halfway between the Serra Giannicola and the hill of Zoccolaro, which I proposed to my companion to call the axis or cone of Trifoglietto. At the same time I sketched out an ideal section (see fig. 15), which I afterwards reduced to a true scale, by aid of that given by M. ABICH in fig. 2, pl. 9 of his 'Illustrative Views of Vesuvius and Etna.'

I had seen, during my ascent to the summit of Etna in 1828, that the beds in the Cisterna, more than 3000 feet above the base of the Serra Giannicola and near the edge of the elevated platform called the Piano del Lago, have a gentle dip of about 6° in nearly an opposite direction. I therefore now inferred that Etna must have had at one period a double axis, or two points of permanent eruption, like some of the great volcanos of Java described by JUNGHUHN*, and that there may have been a saddle as that author terms it, or as I propose to call it, an *intercolline*† space between the two cones (as

* Some of these Javanese cones are nearly comparable in size to Etna, and have had two or more centres of eruption. One in particular called Gede may be cited, in which one regular cone, sloping on some of its sides at an angle of 30°, is truncated like Etna and is 9326 feet high; while the other twin cone, Panggerango, somewhat less lofty, has suffered much waste, being cut into on one of its sides by a deep valley comparable to the Val del Bove. The saddle connecting the two mountains is 7870 feet high.—JUNGHUHN'S 'Java,' vol. i.

† In volcanic regions of subaërial origin there are valleys not formed by aqueous erosion, nor by subsidence, nor by anticlinal or synclinal flexures, but simply by the building up on two or more sides of volcanic hills or chains of hills. Mr. HARTUNG and I found many such valleys or spaces in Madeira, and we found it very convenient to have a technical term for them, such as *intercolline.*

Fig. 15.—*Ideal section of Mount Etna, from West 20° N. to East 20° S., to illustrate the theory of a double axis of eruption.*



A. Axis of Mongibello.
B. Axis of Trifoglietto.
a' c and *b' i d.* Older lavas, chiefly trachytic.
c e and *d f.* Lavas, chiefly doleritic, poured out from A after the axis or focus B was spent, and before the origin of the Val del Bove.
g g. Scoriæ and lavas of later date than the Val del Bove.
h i k. Val del Bove. The faint lines represent the missing rocks.

N.B. In the section between *i* and *k*, it will be seen that the beds at the base, or near *i*, dip steeply away from the Val del Bove, those in the middle, or below *k*, are horizontal, and those at top, or at *k*, dip gently towards the Val del Bove (see pp. 741 and 742).

L. Older Tertiary and Secondary rocks, chiefly sandstones.

between *c* and *d*, fig. 15), a space gradually filled up by lavas and fragmentary matter, the stratification of which would be occasionally horizontal, and always much less inclined than that formed where two cones have not mutually interfered with each other's regular growth. If, then, we name one of the two centres the axis of Trifoglietto, as before suggested, we may call the other, or the present great centre of activity, the axis of Mongibello, the modern Sicilian appellation for Mount Etna.

The late MARIO GEMMELLARO is cited by M. E. DE BEAUMONT* as having first suggested the idea "that Etna was not a simple cone with a single axis, but was made up of two cones, one of them composed of the more ancient rocks (namely, those seen in the Val del Bove), the other of more modern products. The former, he observed, is placed at a short distance to the east (un peu à l'est) of the other, and is not entirely embraced by the products of the more modern cone." The same experienced observer (MARIO GEMMELLARO) first remarked, that in the modern eruptions of Etna, when lateral cones are thrown up in a linear series, they radiate towards the present crater (or towards the axis of Mongibello), as if the rending of the mountain proceeded from that great central focus.

The former existence of an old centre of eruption in the Piano del Trifoglietto, was inferred from independent evidence by S. VON WALTERSHAUSEN†, *i. e.* from observations first made by him on the convergence towards a middle point in that area of thirteen or more dikes of greenstone visible in the surrounding escarpments, one of them of enormous dimensions, or 70 feet in width. The same geologist, after minutely scrutinizing the structure of those rocks which project like gigantic buttresses from cliffs 2000 and 3000 feet high between the Giannicola and the Rocca del Corvo (including, therefore, the cliffs below the Montagnuola), ascertained that while the beds dip at high angles inwards or towards the escarpment (*i. e.* away from the Val del Bove), in the lower half of the precipices they become horizontal in the middle portion, and towards the summit dip as if they were sloping away from some other point near the present great centre of Mongibello. He found in the rocks called by him Teatro Piccolo and Teatro Grande (see Map, Plate L.), above the base of the Serra Giannicola, where I noticed the steep north-west dip of the trachytic formations, a nearly horizontal stratification in beds intersected by a multitude of vertical dikes.

Signor G. G. GEMMELLARO and I had an opportunity in 1857 of verifying these observations, so far as regards the steep south-west dip of the beds in the lower half of the cliffs below the Montagnuola; and when we looked down from the top of the precipice, called in S. v. WALTERSHAUSEN's map the Schiena del Asino, we saw the unconformable inclination of the superior doleritic lavas, which is well expressed in plate 7 of 'The Atlas of Etna.' We were also struck with the obvious convergence of a multitude of vertical dikes, in the precipices below the Montagnuola and in the Balzo di Trifoglietto, towards the present centre or axis of Mongibello. The whole of these phenomena,—the change of dip in the inferior, medial, and uppermost beds of the Giannicola, the

* Recherches sur l'Etna, p. 124.

† Atlas, V. and VI.

corresponding unconformability of the formations in the cliffs below the Montagnuola (in the rocks called by S. v. WALTERSHAUSEN Vavalaci, Intermedia and Cuvigghiuni), the convergence of countless doleritic and other dikes towards the axis of Mongibello, as well as of the thirteen or more greenstone dikes radiating to the centre of Trifoglietto,—all become explicable as soon as we admit the theory of a double axis. We may assume the existence at an early period of two permanent centres of eruption (whether contemporaneous, like Kilauea and the summit crater of Mount Loa in Owhyhee, or successive, like Somma and Vesuvius), and at a later period the complete ascendency of what is now the principal focus, that of Mongibello, which continues in full vigour, while that of Trifoglietto has long been spent. The latter may have been always a subordinate vent, communicating at a great depth with the main chimney, which may never have materially shifted its position from the first.

It would clearly be unsafe to assume, because the upper part of Mongibello is newer than the entire cone of Trifoglietto, that therefore the latter is the more ancient volcano of the two. What is now the great cone may have attained half or two-thirds of its actual height (from A to *c*, fig. 15, p. 740), and may possibly have been a trachytic mountain before the focus of Trifoglietto came into play. The magnitude and volume of what is now the principal cone, having its centre situated at the distance of three miles from the axis of Trifoglietto (and therefore rather more than "un peu à l'est"), imply that at that point (the axis of Mongibello), throughout longer periods of time than anywhere else, the expansive gases and rivers of melted stone have found their freest and most copious discharge. But as we have no sections to enable us to determine the relative antiquity of the two foci, it would be unprofitable to enter more at length into a discussion on the point *.

[During my third visit to Etna in 1858, I had opportunities of corroborating the observations of S. v. WALTERSHAUSEN respecting the dip of the successive lavas, scoriæ, and tuffs in the Giannicola and in the other great precipices under the Montagnuola. For this purpose I made two descents, one after sleeping at the Casa Inglese from the margin of the Piano del Lago to the base of the Giannicola, and another from the Montagnuola, by Cuvigghiuni, Rocca Intermedia and Vavalaci to the base of the same cliffs near the Rocca del Corvo. The steep inward inclination of the older or inferior beds near the foot of each great cliff is precisely as described by S. v. WALTERSHAUSEN, and just the reverse of the direction we should have anticipated had the highest part of the mountain or the axis of Mongibello been a great centre of upheaval. Midway in one of these lofty cliffs (in the Teatro Grande) I met with a mass perfectly horizontal, consisting of compact rock, 40 feet thick, with vertical columns, yet having an upper crust of scoriæ as well as a lower scoriaceous substratum, in a word, having all the characters of a modern current like that of 1669 at Catania, and like it resting on a red band of burnt tuff. Nothing

* [Since the above was written, I have received (February 1859) Part VII. of S. VON WALTERSHAUSEN'S 'Atlas,' in which I observe the cone of Trifoglietto (or G of pl. 24) is supposed to be the oldest part of Etna. It is certainly the oldest visible part, but I see no reason for retracting the views above set forth.]

can be more striking than the absence here, deep in the internal framework of Etna, of all disturbance, just where it ought to have been most manifest, had there been any truth in the upheaval theory; since as we climb up, we are always approaching nearer to the great central axis or highest cone. Lastly, I found a south-easterly dip at angles varying from 7° to 15° in the upper mass, 800 or 1000 feet thick, composed of old lavas and beds of fragmentary matter below the Torre del Filosofo and Cisterna, a state of things irreconcileable, so far as I can see, with any hypothesis save that of a double axis, as above mentioned*.

It is right, however, to mention in this place, that at the upper edge of the precipice under the Montagnuola I observed a slight northerly dip in certain tuffs and lavas, as shown at *c*, fig. 16. This dip I ascertained not only on close inspection, but on viewing them from a distance of nine miles east, or near Bongiardo. They appear to be a continuation of those beds which are seen below the Cisterna at *b*, *a*, but as the natural sections are not complete we cannot prove their prolongation. Such an exceptional inclination *towards* the axis of Mongibello may suggest the idea of an independent centre of eruption at or near the site of the Montagnuola, or if the beds belong to the same system as *a*, *b*, they may have been slightly tilted by movements which accompanied the two great eruptions to which the older and newer craters and cones of the Montagnuola owe their origin. That the older of these cones was due to eruption as well as the newer, is a conclusion to which I arrived after exploring it in 1858, and Signor G. G. Gemmellaro tells me that since I was there he has visited it and has come to the same opinion. It must at least be admitted, that, had the steep dips in the older of the two cones been due to upheaval, as some have suggested, the beds in the great escarpment at

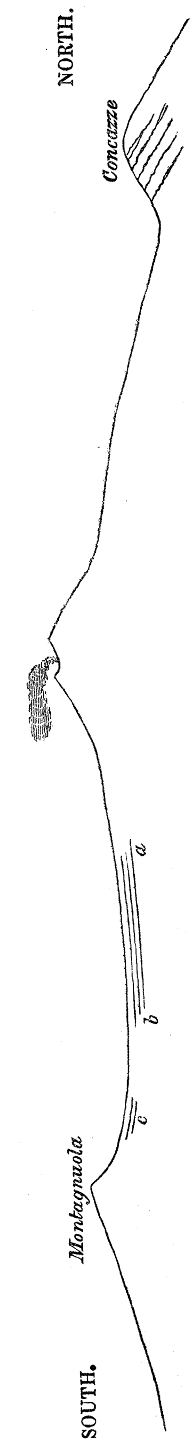


Fig. 16.—*Outline of eastern summit of Etna with dip of some of the uppermost beds, as seen from near Bongiardo, about nine miles east of the Montagnuola.*

a, *b*. Lavas and scoriæ with south-south-easterly dip.

c. Same with northerly dip.

* I had the pleasure of receiving a letter, dated March 3, 1858, from M. Abich, full of valuable drawings, illustrative of the structure of Etna, which has been published in the 15th vol. p. 117, of the Geological Society's Quarterly Journal for 1859. Among other sections, that distinguished geologist has given one (fig. 6, p. 121, *ibid.*) to show the "almost horizontal position" of the beds high up or in the middle of the precipice of the Serra Giannicola observed by him in 1834. He also speaks of a double axis of Etna, the older one to the east of the present centre, but he treats the subject too briefly to enable me to judge how far his views coincide with those set forth in fig. 15, p. 38.

c, fig. 16, and those immediately below in the same cliff exposed in Cuvigghiuni and other rocky promontories, could not have retained the undisturbed and nearly horizontal position which they now enjoy.]

Comparison of the twofold axis of Etna with that of Madeira.

The analogous structure of the island of Madeira, where there is also a twofold axis of eruption, encourages me to believe that the mode of origin above ascribed to Mount Etna is correct. My fellow-traveller, Mr. HARTUNG, and I found in 1853–54 that the lavas have flowed in Madeira chiefly from one main axis or chain of volcanic vents, thirty miles in length, and have overwhelmed the materials eructed from a shorter chain which runs parallel to the other. In the case of the Sicilian Mountain, we have a larger cone overwhelming and burying a smaller one; whereas in the case of the Atlantic island, we have a linear series of volcanic cones, rising at some points to a height of 6000 feet, whence lava and scoriæ have been poured, which have not only filled up the intercolline space, but have so overtopped the secondary chain, as to bury it under a stratified mass 2000 feet in thickness. In both cases there is a difference in the mineral composition of the older and newer lavas, although the order of their relative age is reversed, the trachytic lavas in Madeira being the more modern of the two. In both volcanic districts there is a deep crateriform valley, which to a certain extent cuts through the products of the two axes, for such is the celebrated Curral in Madeira, 4000 feet deep towards its upper extremity and 3000 feet deep, where it intersects the secondary chain at a distance of two miles from the main axis. Nor does the analogy end here; for in the same manner as we see on the west side of Mount Etna towards Bronte (see fig. 15, p. 740), where no lateral cone like that of Trifoglietto interfered with the regular growth of the volcano, that the lavas slope steeply from the elevated platform down to the base, so in Madeira, on the north side of the main axis, the lavas have a uniform steep inclination to the sea, there being on that side, as the numerous ravines show us, no lateral buried chain which could present any obstruction,—no intercolline space like that on the southern slope to cause the lavas to become horizontal*.

It follows as a corollary from the views above set forth, that in the cone-making process the force of upheaval from below, if it has acted at all, has only exerted a subordinate and possibly a very local influence, and the admission of a double axis for Etna draws with it the abandonment of the "elevation-crater" hypothesis; for however conceivable it may be that one cone of eruption should envelope and bury an adjoining cone of eruption, it is obviously impossible that one cone of upheaval should mantle round, overwhelm and bury another cone of upheaval.

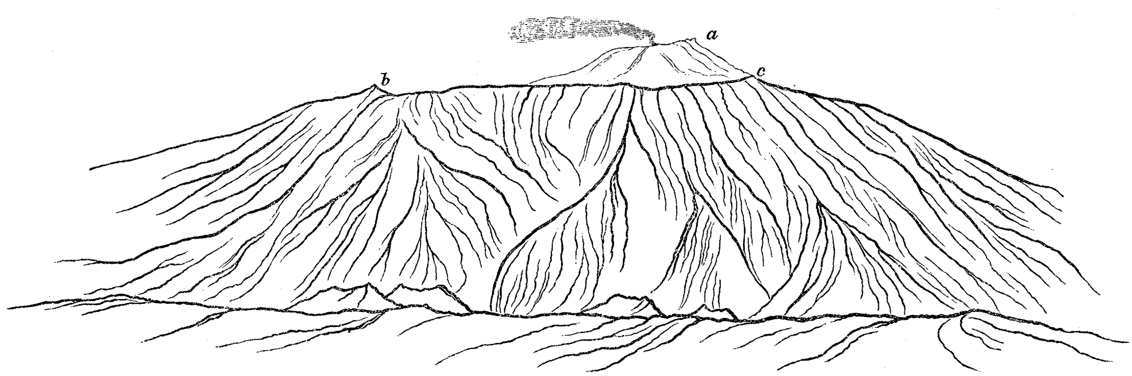
* See section of Madeira, 'Manual of Geology,' chap. xxix. fig. 653, p. 517, 5th edit., where A is the central axis, *s* R the intercolline space filled up, and *c f* the secondary chain buried under 2000 feet of lava and scoriæ.

Want of continuity in the older and modern parts of Mount Etna, and truncation of the summit.

The evidence on which some writers rely in proof of a discontinuity of the operations which produced the old nucleus of Etna, and those which formed the more modern portion of the mountain, seem to me far from conclusive; for on the north-west, the west, and part of the south-west sides, there may have been a regular and almost uninterrupted superposition of conformable volcanic products, from the oldest known trachytic to the most modern doleritic lavas*.

S. von Waltershausen has shown that the oldest series of dikes intersecting the lavas are dioritic, only one dike of trachyte having been seen by him. Next to the dioritic or greenstone dikes come those of a kind of slaty basalt, to which he gives the name of phonolite, while the third and last series consists of dolerites and greystones, or "trachi-dolerites." That in certain parts of the mountain particular sets of lavas should be found resting unconformably on other and older rocks was to be expected, as the necessary consequence of three great events which have successively worked a change in the physical geography of Etna; namely, first, the interference of the products of the two foci, or the overflowing of Trifoglietto by the newer part of Mongibello, as before described (fig. 15, p. 740); secondly, the truncation of the summit of Mongibello, to which I shall presently advert; and thirdly, an event in part perhaps contemporaneous

Fig. 17.—*Truncated appearance of the summit of Etna on the north-west side, as seen from near Bronte, from* Sartorius von Waltershausen's Atlas, plate 2.



a. Modern cone. *b, c.* Margin of convex area or highest platform.

with the last mentioned, the formation of the Val del Bove,—that wide and deep chasm into which so many floods of lava have since been poured, as if the eruptive powers

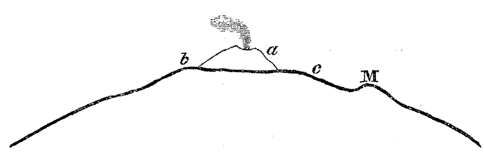
* The rock here called trachyte, is so designated by MM. S. v. Waltershausen and Abich, as it appears to me with propriety, although von Buch considered the name inappropriate, because the felspar he says is labradorite and not glassy felspar. The ordinary appearance of the felspar, whether in the older or newest lavas of Etna (including that of 1852), is like glassy felspar, so far as having the same vitreous lustre. The composition of the mineral in the trachytes above alluded to is said by S. v. Waltershausen to be intermediate between labradorite and oligoclase. Crystals of hornblende and of augite accompany it, but no quartz, —mica very rarely, and only as an accidental mineral.—S. v. Waltershausen's Atlas, V. and VI. p. 3.

were striving to repair the injury done to the symmetry of the cone, and restore to the volcano its proper and normal shape.

That the cone of Mongibello was once higher, and that, like a large number of active volcanos, its summit has been truncated, appears from the occurrence at the height of more than 9000 feet of a convex platform, which, according to S. v. WALTERSHAUSEN'S measurement, is 4150 metres in its longest, or S.E. and N.W., and 3000 metres in its shortest diameter.

[The annexed outline view (fig. 17) will show the manner in which the modern cone (*a*) rises from near the western margin of the platform (*b*, *c*), which S. VON WALTERSHAUSEN considers as the remnant of a crater named by him the "Cratere Elliptico" nearly filled up, but part of the outer wall of which still remains, and which will be described in the sequel. The area called the Piano del Lago, situated at a lower level to the south of the highest cone, is regarded by the same observer as marking the site of another distinct centre of eruption, or filled-up crater, 2600 metres in diameter; but I was unable to verify this opinion, there appearing to me no sections sufficient to establish the fact of a long-continued series of eruptions from any fixed point, other than the present culminating focus. There is, however, such a tendency in volcanos to shift their principal points of discharge, that a geologist cannot object to such an hypothesis, if it can be shown that we can thereby best explain any observed phenomena; and it was probably owing to the limited period of my visit, that I failed to obtain proofs of two adjoining craters formed by paroxysmal explosions and then afterwards filled up to the lips by lava and scoriæ.

Fig. 18.—*Summit of Etna as seen from the south or the eastern suburbs of La Motta.*



a. Highest cone as seen from La Motta. *b*, *c*. Margin of Piano del Lago. M. Montagnuola.

The annexed sketch (fig. 18), which I made of the outline of the higher region, as seen from the south or from the eastern suburbs of La Motta, will show in how analogous a manner the modern cone rises there above the Piano del Lago.

The geologist must not infer, from the term Piano, that there is really any extent of level ground or table-land near the summit of Etna. The whole area surrounding the cone might rather be compared to a flattened dome, from which rise several volcanic hills of considerable size, such as that of the Torre del Filosofo, and another much more lofty, called Monte Frumento, rising due south of the Casa Inglese. These have the ordinary external characters of lateral cones produced by single eruptions.]

[*Elliptical crater.*—I regret that I was unable to visit what is still extant of the walls of the "Cratere Elliptico" of S. VON WALTERSHAUSEN, which is situated north and north-

west of the great cone (see Map, Plate L.); but my friend, Signor GAETANO G. GEMMELLARO, has had the kindness to explore it at my request, and has communicated to me for publication an account of it, in a letter dated Catania, October 18, 1858, in which he replies fully to the numerous questions I had put to him. He found the eastern remnant of the old crater-wall (that lying east of the lava of 1809) almost concealed under recent volcanic sand and fine scoriæ, to such an extent that it was extremely difficult to determine even the site of the ruins which S. VON WALTERSHAUSEN discovered many years ago. But the other fragment which lies to the west of the recent lava of 1838, "is still," says Signor GEMMELLARO, "clearly exposed to view, forming for 1100 paces an arc of a circle round the present axis of Etna; its mean height 11 metres, or 36 English feet. It is composed of alternations of lavas and fragmentary materials, or scoriæ, sand, and lapilli, its upper margin broken and serrated. The lavas, except the bottom bed, which is nearly 6 feet thick, are thin but compact, the upper beds, however, becoming more cellular. All the lavas are inclined steeply to the north at an angle of 31°, the average of many measurements. Most of them are continuous from one end to the other of the elliptical crater, but some of them thin out in their extension from east to west. They are not strictly parallel, but present slight undulations. Several dikes occur, of which two especially are conspicuous. The principal one is 3 metres wide, of a reddish colour and schistose fracture, and decomposing rapidly. It does not reach the upper part of the precipice, but terminates about half-way up. The direction of both dikes is nearly north and south, or exactly towards the centre of the present axis of Etna. The smaller one has the same structure as the larger, but its thickness is much less."

In conclusion, Signor GAETANO believes "this elliptical crater of Baron S. VON WALTERSHAUSEN to be a fragment of the ancient cone of the actual axis of Etna, destroyed by earthquakes and the explosive force of gases during one or many eruptions; also that the epoch of that catastrophe may not be very remote, geologically speaking; for in the works of RECUPERO, FERRARA, and ALESSI, we find,—1st, that SENECA reminds LUCILIUS that Mount Etna had in his time lost so much of its height that it could be no longer seen by boatmen from certain points whence it was previously visible; 2ndly, UGONE FALCANDO, referring to FILOTES, relates that the lofty summit of Etna had fallen in, in 1179, in the time of WILLIAM the Eleventh; also that it was destroyed, for the third time, in the reign of FREDERICK the Eleventh, in the year 1329, as FAZZELLO relates. Moreover, that it was engulfed, for the fourth time, in the year 1444, according to the authority of the same writer, and of FILOTES and CARRERA; and finally, in the year 1669, nearly the whole top of the mountain fell in*."

If within the last 2000 years such revolutions have been witnessed in the upper region of Mongibello, it may well be supposed to have experienced a far greater transmutation by the reiterated catastrophes of the ten or twenty thousand years which immediately preceded the historical period, during which time there may have been, within the area of the highest platform, several summits blown off, and several deep craters formed and

* ALESSI, Storia critica dell' eruz. dell' Etna, p. 149.

filled, and possibly some centre of discharge, bearing to the actual crater the same kind of relation which the Chahorra now bears to the Peak of Teneriffe.

I found on the summit of the highest cone, when I visited it, September 21, 1858, two craters, one, the western, much smaller than the other, and separated by a narrow wall of highly inclined beds of ejected scoriæ from the chief abyss, implying that within this limited space the modern eruptions have not been strictly constant to one focus.

Junghuhn infers, from his experience in Java, that where there are two permanent foci of eruption in the same mountain, they are to be considered as a fragment of a chain of volcanos. If a third occurs, as sometimes happens in one and the same Javanese group, the three are always linearly arranged. In like manner, S. von Waltershausen imagines that in the upper part of Etna (or the area of the axis of Mongibello) the two ancient centres, before alluded to, are in a line running N. 36° 48′ W., which, if prolonged, would strike the axis of Trifoglietto. He therefore supposes all the eruptions of these three foci to have broken out along one great fundamental fissure*. I was unable, as before stated, p. 746, to find sections to test or bear out these generalizations.]

By reverting to the section (fig. 16, p. 743), the reader will see that the great northern escarpment of the Val del Bove, called the Concazze, terminates in its higher or western extremity in a precipice, which faces the present active cone or axis of Mongibello, and consists of lavas which dip steeply away from that axis. When this elevated portion of the Concazze was formed, the great crater of eruption may perhaps have been more to the north than now, and the cone was probably loftier than that which now exists. Be this as it may, we cannot account for the present shape of the northern and southern escarpments of the Val del Bove, and the manner in which they slope away from the highest cone, without assuming that before the Val del Bove originated there was but one conical mountain, which embraced within it the subordinate and buried cone of Trifoglietto. By this hypothesis alone can we explain the superior altitude of the western boundary of the great valley, and the gradual diminution in height of the two great escarpments as they trend eastward.

The reader will be better able to restore in imagination the former outline of the single cone, before it was truncated at the top, and before it was indented by the great valley on its eastern flank, by referring to plate 12 of S. v. Waltershausen's 'Atlas,' where an accurate and very descriptive view is given of the eastern slope of Etna, including the Val del Bove, as seen from the Torre d'Archirafi, a point south of Riposto, on the sea-coast.

Hypothesis of upheaval by injection.

I have stated, in my preliminary remarks, that geologists, who take for granted that lava cannot congeal in continuous stony layers on slopes exceeding five or six degrees, must unavoidably embrace the conclusion that nine-tenths of the strata which constitute the nucleus of Etna, and not a few of the beds which overlie that nucleus unconform-

* Atlas von Etna, part 7. p. 3.

ably, were brought into their present position by mechanical forces after the materials of the mountain had accumulated on nearly level ground.

It has been suggested by M. Elie de Beaumont, that when (as during the eruption of 1832) new fissures are produced, radiating from the centre, and traversing the nucleus of Etna, and when lava, after rising simultaneously to the rim of the highest crater, has filled such fissures, there may result an upheaval of the whole cone, and in this way the tumefaction or distension of the mass may have been going on. He even thinks that the cone may acquire as much height by this machinery as by the accession of new external coats of lava.

I may first be allowed to remark, that if such a doctrine be embraced, it would help us to dispense with that paroxysmal violence or grand terminal catastrophe which holds so prominent a place in the "crater-of-elevation" hypothesis.

[Unfortunately we have at present no data for deciding whether the dike-making process thus appealed to is usually attended by upheaval. That on some occasions it indicates a collapse and partial subsidence of the flank of the cone in such a manner as might either increase or diminish the angle of dip, seems proved by the observations of Scacchi on Vesuvius in 1850 and 1855, and by those of Julius Schmidt in 1855. The last-mentioned observer looked in vain, in the walls of the long cavity caused by subsidence (and in which probably a new dike was forming by injection of lava into the flanks of the cone), for signs of upheaval*.

That an uplifting of the incumbent mass must accompany the injection of liquid matter through fissures which are not perpendicular, some of which, as I saw in the Serra Intermedia, are inclined at an angle of 75° to the horizon, no one can deny. Such injected rents, when very wide, must modify greatly the position of the overlying and intersected beds, both in a horizontal and vertical direction. S. von Waltershausen, therefore, while rejecting the hypothesis of a single terminal catastrophe, or any paroxysmal development of the elevating force, ascribes no small influence to those disturbing operations, by which such innumerable dikes have been formed near the principal centres of eruption.]

The same author, who has studied Etna for a longer time and more attentively than any other geologist, supposes the volcano to have assumed its present form and dimensions gradually by the joint effect of the overflowing of lava and the injection of the same, not only into vertical fissures, but in sheets parallel to the previously deposited tuffs and lavas. By these intercalated and conformably intruded masses, according to him, much elevation has been brought about, an hypothesis to the discussion of which I shall presently return. The great point to be chiefly kept in view in the present memoir, is simply whether the quâquâversal arrangement of the beds, in cones like Etna and Somma, and the high inclination of the lavas and scoriæ, are not mainly, and in many cases exclusively, due to eruption, and whether the upheaving power, even granting its intervention, does not play a very subordinate part. On this head we may con-

* Die Eruption des Vesuv im 1855, p. 44. (Wien, 1856.)

sider which of two propositions is the more likely to be true; first, the one advanced by M. ELIE DE BEAUMONT, that a large portion of the strata in the nucleus of Etna, as seen in the Val del Bove, and now dipping at an angle of 28°, had an original slope of only 5° or 6°, the remaining 20° or 22° being due to upheaval; or secondly, the converse of the above, namely, that 23° may have been the original average inclination, and that the additional 5° or 6° may have been gained by subsequent movements,—in other words, a fifth part alone of the whole dip, save in a few exceptional cases, may be ascribable to elevation.

In favour of the doctrine that the lavas and tuffs of Etna have been subjected to disturbing forces, two arguments have been advanced; first, it is said that the rocks of fusion, as well as those composed of fragmentary materials, are inclined in many places at angles steeper than those at which they could possibly settle on the slope of a volcanic cone; 2ndly, that in the Val del Bove alternate strata of rocks of both kinds preserve a uniform thickness and parallelism over exceedingly wide spaces, entire sets of them preserving their parallelism at points where they are all bent at once, and made to assume a new position with quite a different dip (see below, p. 753). I shall begin by considering the first of these arguments, the only one, according to my observations, to which any real weight can be attached.

The steepest dip of beds in the modern or highest cone of Etna amounts to 39°; the most considerable which I saw in Vesuvius was on the exterior of a small cone, then in the process of growth (October and November 1857), where the slope was 42°; but in that case, as before stated, p. 737, I believe the scoriæ, which were red-hot, and which formed a sheet of matter glowing like lava after it had fallen, to have been in such a state of semifusion as to be capable of becoming agglutinated or soldered together.

Every observer will grant that the dip of nine-tenths of the lavas, tuffs, and agglomerates seen in sections of the Val del Bove, fall short of the angles above alluded to, and that by far the larger part of them are under 30°. The steepest inclination which I measured was in the outlying rock in the Val del Bove, called Finocchio Inferiore, where the beds, consisting of red scoriæ, with a few intercalated layers of lava, dip at one point, at angles as high as from 45° to 47°, towards the N.W., whereas other beds near them, and separated only by a dike, dip from 30° to 38° N.E. The scoriæ here are of such a nature as might originally have had a very steep dip, and they are traversed by so many dikes, some vertical, others many degrees out of the perpendicular, that no geologist would deny that local fracture and subsequent dislocations may have operated as disturbing causes, to say nothing of the possibility of such an outlier having had its position altered bodily by that subsidence, and those explosions to which we refer, in part at least, the origin of the great valley.

[In the lofty escarpment of the Serra del Solfizio, near the Montagnuola, the beds of lava, scoriæ, and fragmentary matter (the latter greatly preponderating in volume over the lava) are horizontal, or nearly so, in the upper half of the precipice, while in the lowest, 800 or 1000 feet, they have a steep inward dip away from the Val del Bove.

This arrangement of the beds, first observed by Baron S. VON WALTERSHAUSEN, I verified, as before stated (p. 741), in 1858, in the projecting promontories of rock called Cuvigghiuni, Serra Intermedia, and Vavalaci (see Map). In one of these (Cuvigghiuni) S. VON WALTERSHAUSEN counted no less than forty dikes of various ages, which have invaded the inclined strata, the oldest dikes, composed of greenstone, being often of great width, and being crossed and shifted by the more modern or doleritic ones, and many of both kinds being out of the perpendicular.

Here and in the adjoining Serra Intermedia, there are points where the volume of the intrusive matter seems equal to the rocks which they penetrate, and we cannot therefore be surprised if, under such circumstances, we should see, in the lower half of the escarpment, dips exceeding 40°, an inclination which we cannot ascribe to the original position of the beds. But after measuring the dip at numerous points, even here, where the dikes most abound, I found it rarely above 33°, while occasionally it only amounted to 15°. Amidst all these variations I saw no case of a reversed dip, or a dip towards the Val del Bove.]

The beds in the lower half of the Serra del Solfizio were probably from the first very steeply inclined, for they consist chiefly of agglomerates, containing many angular fragments of lava, implying a neighbouring vent; and we need not perhaps attribute more than a fifth part of their present dip to a tilting of the mass by subsequent disturbances.

The fact that the steepest dips occur where the dikes are most numerous, may be thought by many to favour the doctrine that the high inclination of the beds was the effect of the injection of melted matter into such innumerable fissures. Without denying that it may sometimes have been an auxiliary cause, we must, on the other hand, remember that the dikes are always nearest the great centres of eruption, and that there are three reasons why the original dips should be greatest near such centres:—1st, because the heavier and larger fragments of rock thrown out of the crater fall nearest to its margin; 2ndly, because the red-hot scoriæ, as before mentioned, are sometimes agglutinated together; and 3rdly (an influential circumstance too often overlooked), because streams of lava frequently stop short when they have crept but a small way down the declivity of the cone. [The effect in steepening its flanks of this midway halting of many lavas, was strikingly exemplified high up on the north slope of Vesuvius, between the years 1855 and the close of 1857, especially in July of the year last mentioned. The inclinations of the recent lavas observed by Signor GUISCARDI and me, amounted to 30° and 35°, and even for short distances, 39° and 42°.]

[*Supposed frequent injection of lava in beds conformable to tufaceous strata, considered.*

It has been already hinted (p. 749) that S. VON WALTERSHAUSEN attributes much of the upheaval of the mass of Etna to the intrusion of conformable lavas between previously deposited layers of tuff and fragmentary matter. He ascribes, for example, such an

origin to most of those lavas of Sciuricosino near Zafarana, which are bent into arches, and which thin out in both directions, as represented by him in plate 20 of his 'Atlas.' Yet these occur far from the region where dikes are frequent, and where we have positive proof of the injection of melted matter into rents. That near the great centres of eruption, where the hade of the many dikes is so much out of the perpendicular, and where some are tortuous, and are seen to cross and shift others, there should be found occasionally sheets of intrusive matter parallel to the tuffs and older lavas, will be readily conceded. Mr. HARTUNG and I observed in Madeira, at the western extremity of Cape Giram, some dikes which were nearly horizontal, and had been injected, for a certain portion of their course, between sheets of pre-existing lava; but these dikes, like some of similar origin above Guimar in the Island of Teneriffe, were ascertained by us, when we traced them for 30 or 40 feet, to cut through the regular lavas and tuffs; and in the case of Cape Giram in Madeira, they give rise to faults in the older beds, a rare phenomenon in Madeira, as it is also on Mount Etna.

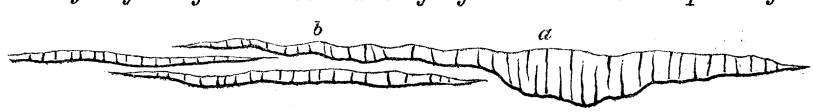
Had the lavas which slope away from the ancient centres of Trifoglietto and Mongibello been in great part injected between the tuffs, we should have frequently seen them penetrating through the dikes. But though these last are of so many different ages, and are continually seen to traverse the alternating lavas and tuffs, I could discover no instance of such dikes being in their turn traversed by the lavas. It may be asked how, in the escarpments of the Val del Bove, we can distinguish a lava, which has flowed originally at the surface, from a tabular mass of rock, which may have been forced, when in a melted state, into a fissure betwen two layers of tuff? I reply, that the lava has almost invariably its upper and lower scoriæ, and sometimes immediately beneath the latter a red layer of burnt tuff, such as I saw in the Balzo di Trifoglietto, at various heights, and in Monte Zoccolaro and in the valley of S. Giacomo, where I traced a red tuff for a great distance underlying the most powerful of the older lavas. Such red layers are never in direct contact with the central and overlying crystalline stony layer, for there intervenes always a fundamental stratum of fragmentary or scoriaceous matter between the stony bed and the burnt tuff below. On the other hand, I looked in vain for an instance of some powerful sheet of lava which had one of these brick-red clays *above* as well as below it. Had the crystalline lavas, whether trachytic or doleritic, whether slightly or steeply inclined, been in great part intrusive, they would have altered the tuffs as much above as below them. Moreover, they must have given rise to innumerable faults; for while they vary in thickness from 3 to 60 feet, they are not, as I shall show in the sequel, persistent for indefinite distances, but often thin out rapidly in both directions. They ought, therefore, had they been injected, to have lifted up the incumbent deposits partially, so as to give rise to many conspicuous faults. For these reasons, I cannot adopt the conclusion that the upheaval of Etna has been largely due to the injection of lavas in sheets parallel or conformable to the tuffs and fragmentary materials.]

Evidence of pseudo-parallelism and want of uniform thickness of the beds forming the escarpments of the Val del Bove.

M. ELIE DE BEAUMONT, in his celebrated Essay on Mount Etna before cited, has represented the escarpments of the Val del Bove as being composed of many hundreds of perfectly regular beds, formed alternately of rocks of fusion and of fragmentary and pulverulent materials. He describes the thickness of the beds as varying from a few inches to several yards, but averaging about 6 feet each, the fragmentary beds being generally, though not always, thicker than the lavas. At the same time, he insists on the remarkable uniformity in thickness and parallelism of the several members of this whole series, and their continuity for great distances, a fact adduced as confirmatory of the doctrine that the beds were originally horizontal, and were afterwards brought by upheaval into their present position. The same author states, that "the most general and the most conclusive character of the numerous beds of fused and fragmentary matter consists in this, that they are liable, all of them, to be bent together as they pass in several different directions, from a nearly horizontal position to an inclination of from 25° to 30°, without either their structure or their thickness being altered with any degree of regularity*." The volcanic strata are therefore likened by him to the regular sedimentary formations which have undergone great flexures in mountain chains.

To begin with the northern escarpment of the Val del Bove, we obtained (Signor G. G. GEMMELLARO and I) a good general view of the precipices composing it, from Monte Finocchio Inferiore and its neighbourhood. First we turned our attention to part of the nearly vertical cliff immediately N.E. of our station, where the height exceeds 1000 feet. It was called by our guide the Serra di Cerrita, and is part of the Concazze. We could count in this part as many as sixty beds, more solid and prominent than the rest, which we had no doubt were lavas or rocks of fusion, and we recognized in the series many marked deviations from parallelism. One case in particular was very conspicuous, for a single bed of rock (*a*, fig. 19), the thickness of which we estimated roughly at 40 feet, was represented or replaced, at the distance of a few hundred yards westwards, at *b*, by

Fig. 19.—*Want of uniformity in thickness in stony layers in northern escarpment of Val del Bove.*

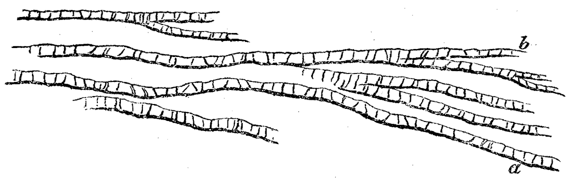


Thickest part of *a* 40 feet.

* "Le caractère le plus général et le plus concluant de ces nombreuses assises de matières fondues et de matières fragmentaires qui alternent pour former le noyau de la gibbosité centrale de l'Etna m'a paru consister en ce qu'*elles sont sujettes à s'infléchir toutes ensemble, en passant dans plusieurs directions diverses, d'une position à peu près horizontale à une inclinaison de* 25° *à* 30°, *sans que leur structure ni leur épaisseur en soient altérées d'une manière constante.*" The italics are in the original. Mém. pour servir, &c., pp. 130, 131. Again, we find, p. 165, "l'uniformité d'épaisseur et l'exacte parallelisme que conservent au milieu d'inflexions variées," &c.

two hard beds, with several intervening layers of a different and less solid composition. In another part of the same escarpment, and not far distant in the upper half of the cliff, the harder beds presented the irregularities sketched in the annexed woodcut (fig. 20), the

Fig. 20.—*Non-parallel strata in the northern escarpment of the Val del Bove, to the south of Finocchio Inferiore.*



Vertical distance from *a* to *b* about 60 feet.

aggregate thickness of the mass, including the softer intervening beds, being about 60 feet. Between perfect parallelism and such marked deviations from it, as are here indicated, there is every intermediate gradation.

[In the higher and more western portion of the same escarpment, called the Concazze (or by ABICH the Cima della Valle), where the stratification has been described as very regular and parallel, I distinctly saw a similar thickening and thinning out of the beds as viewed from the rim of the great crater of 1819, the want of parallelism being most conspicuous in the upper parts of the precipice.]

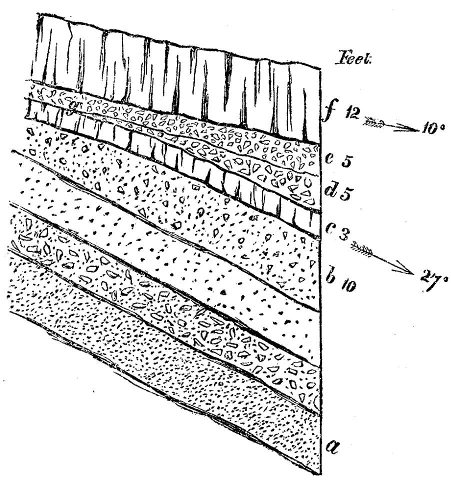
To speak next of the southern escarpment. I may first remark, that when a cliff is between 1000 and 2000 feet in height, like the Serra del Solfizio, we can only obtain a general view of its hundreds of strata by placing ourselves at a considerable distance from its base; in which case all the minor variations in dip and in the thickness of individual beds may escape notice, unless specially looked for.

M. ABICH has given an excellent pictorial representation of this cliff in his eighth plate, taken from the foot of Zoccolaro, and has called attention to the general uniformity and regularity of the lines separating the numerous beds. But even in the Serra del Solfizio, at certain points where the steep cliffs were accessible, and where we measured the angles of dip and the thickness of the beds, we invariably found the appearance of strict parallelism and uniformity of stratification to vanish. Before adducing particular examples, I may observe that, besides the height and magnitude of the section, the number of dikes, mostly perpendicular, but some of them having a considerable hade, and still more the numerous ravines which have been excavated by torrents, causing gaps from 150 to 300 feet in width, add prodigiously to the difficulty of tracing a particular bed for an indefinite horizontal distance. The gaps alluded to cause the intervening promontories of rock to jut out like the side-scenes in a theatre when seen in profile, as is well represented in ABICH'S sketch above cited.

At the first point where we tried to ascertain whether the strata were persistent throughout wide spaces, we found such a want of correspondence on the opposite sides of one of these ravines, that we began to suspect that we had at length discovered a great

fault shifting the beds vertically for several yards; but we soon satisfied ourselves that a gradual change in the thickness of particular beds afforded the true explanation. The ravine alluded to is in the Serra del Solfizio, about midway between the Rocca del Corvo and the hill of Zoccolaro (see Map, Plate L.). It is about 300 feet wide, and runs north and south. The strata consist chiefly of agglomerates, some containing much scoriæ and large angular pieces of lava. We may expect such beds to be more continuous and uniform in thickness throughout wide spaces on the flanks of a volcano than single currents of lava, because during violent eruptions the ejectamenta are scattered by the explosive action of gases and by the winds over extremely large areas. The first mass, about 80 feet thick, which we examined near the base of the cliff, on the west side of the ravine, was divided into beds which varied in their dip from 24° to 28°, when viewed in a north and south direction; while in the east and west section, or that which faces the Val del Bove, we found a want of parallelism in the same beds amounting to 15° in the space of a few hundred yards. In the above-mentioned 80 feet there were only six layers of lava, the united thickness of which was no more than 10 feet. We next observed another vertical mass, on the east side of the same ravine, where the agglomerates were in like manner very preponderant throughout a thickness of 300 feet, the dips varying from 28° to 18°, and diminishing as we ascended. Immediately above we came to another section, represented in the annexed diagram (fig. 21). At the bottom are

Fig. 21.—*Want of parallelism in the beds in the Serra del Solfizio, south side of the Val del Bove.*

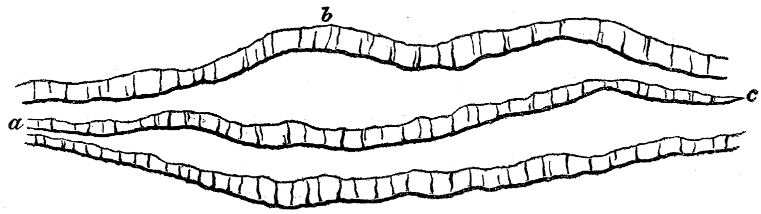


several beds of agglomerate (*a* to *b*); then a doleritic lava (*c*), about 3 feet in its greatest thickness, and inclined at 27° S.; over that again a bed of scoriæ and agglomerate (*d*), 5 feet thick, which at the distance of a few yards thinned out entirely at *g*; above this is another bed of scoriæ and agglomerate (*e*), 5 feet thick; and over that a lava (*f*), 12 feet thick, inclined at 10°; so that here, in a vertical height of little more than 10 feet, the want of parallelism of the two lavas *c* and *f* amounted to 17°.

At the eastern extremity of the Serra del Solfizio in the hill of Zoccolaro, we observed,

among other irregularities, three beds of lava (see fig. 22), varying from 4 to 6 feet in thickness, and separated by strata of incoherent matter. When followed for a distance

Fig. 22.—*Curvatures in the lavas of Zoccolaro.*



of between 200 and 250 feet, the middle bed thinned out at *c*, while the upper and lower lavas, instead of being about 40 feet apart, as below *b*, bend in such a manner as to come within 12 or 14 feet of each other, as at *c* and *a*.

Upon the whole, the term pseudo-parallelism, which Mr. HARTUNG and I were in the habit of applying to the volcanic beds of Madeira and the Canaries, seems to me equally applicable to the Etnean formations, when these are analysed in detail.

Analogous form and arrangement of ancient and modern lavas.

It may still be asked, are there not single continuous beds of lava, intersected in the escarpments of the great valley, of wider extension than we can possibly explain on the hypothesis of their having flowed down the flanks of a volcanic cone in the manner of ordinary lavas?

Before we can reply to this question, we have to consider two points; namely, first, whether the ancient rocks to which we refer are intersected longitudinally, or in a direction transverse to their dip; and secondly, if transversely, what accurate data have we respecting the average width of such beds, whether among the older lavas of Etna, as seen in the Val del Bove; or in the modern products of Etna, Vesuvius, or any known volcano? As to the first question, it is clear that if our sections are longitudinal, that is, in the direction in which the lavas flowed, there is no reason why a stony layer should not be continuous for several miles. Even if the section be diagonal in reference to the original course of the stream, a single layer may be continuous for as great a distance as we are likely to have an opportunity of tracing it in the Val del Bove. The prevailing dip towards the east of the numerous beds there seen, both in the northern and southern escarpments, accompanied as it is by a diminishing height of the mountain as it stretches eastward, implies, according to the theory of eruption, that the currents of melted matter flowed eastward, and are therefore cut open longitudinally or more or less diagonally; whereas the lavas, if any, which came down from the axis of Mongibello after the overwhelming of the cone of Trifoglietto, would naturally take the same, or nearly the same direction.

ꝏ[In regard to the second question, if we admit that some of the lavas and agglomerates which depend on the axis of Trifoglietto are really intersected in a direction at

right angles to their dip, both in the Serra Giannicola and Serra del Solfizio, we soon discover that we are wholly in want of data to test the point at issue. We have no means of ascertaining whether any single stratum is persistent for an indefinite distance in a direction at right angles to the original course of the lava. The sections afforded by the Serra Giannicola and by the rocks under the Montagnuola (Cuvigghiuni, Serra Intermedia and Vavalaci), are all too interrupted to allow us to follow any single bed of rock very far in its line of strike. Even in the Serra del Solfizio the gaps before alluded to impede observation, and we have said enough to show that the alleged continuity and parallelism of the beds in that range of cliff is a delusion. If, on the other hand, we seek information as to the average breadth, depth, and dip of lavas on the slopes of any modern cone, whether near the lip of the crater or half-way down, or near the base of the mountain, we find ourselves still more in the dark. In order to appreciate the truth of this remark, we have only to consult the excellent monograph of Vesuvius recently published by Dr. ROTH of Berlin, in which he has given us a judicious and elaborate analysis of the multitudinous memoirs and treatises on the eruptions of that volcano since the year 79. In consequence partly of the want of sections on the flank of a growing cone, and partly of inattention to facts supposed to be of no theoretical interest, we fail, in spite of the high scientific attainments of so many of the observers, to obtain in any one instance the three data of which we stand in need. Some record the thickness, others the width, others the dip of a given lava-current, or the slope down which it flowed; some few mention two of these conditions, but no one all three; still less do they record facts respecting variations in breadth, depth, and inclination at various points between the summit and base of the cone*.

In S. v. WALTERSHAUSEN'S great map of Etna, we perceive that certain currents, radiating in various directions from the highest crater and platform (see Map, Plates XLIX. and L.), have the appearance of narrow stripes, yet prove, when measured at right angles to their course, to have a width of from 300 to 1800 feet. We cannot ascertain their average depth, but, judging by their external form, they probably exceed in thickness most of the old lavas intersected in the Val del Bove. Nevertheless they

* [Since writing the above, I have found some valuable observations on this subject, published by Mr. JULIUS SCHMIDT of Olmutz, on the lavas of 1855, 'Eruption des Vesuv. im Mai 1855,' p. 56. I have also myself revisited (September 1858) Vesuvius and the Atrio del Cavallo, in company with Signor GUISCARDI of Naples. We measured the depth and width of several lavas of 1857, resting on slopes of 18°, 24°, and 28°, and we compared the results with those supplied by the older lavas in the escarpments of Somma, in order to see if any of the latter were of greater width when intersected transversely to their dip. After surveying many hundreds of layers, we found only one, near the entrance of the Atrio, on the side of the Observatory, decidedly more persistent than the modern lavas examined by us. There are beds having the appearance of hard stony layers which are conspicuous in the walls of the Atrio, and which might easily be mistaken for lavas, but which consist of solid tuffs. The exception which we saw might, we thought, be accounted for by some accidental irregularity in the external slope of the old cone, producing a gibbosity such as has been formed in the last few years on the northern side of the modern Vesuvius, and which, by interrupting the free course of a descending current, might cause it to spread out laterally.]

may be subdivided into several sheets, lying one over the other, just as the lava of 1669 is seen in Catania, in the shaft artificially cut through it near the sea in the Villa Filippino, to be about 80 feet thick, but separated into ten beds, most of them with scoriaceous partings, caused by a succession of flows during the same eruption. This same lava in the northern suburbs attains a thickness of 60 feet in one magnificent crystalline mass, without any such bedding. I allude to the quarries at the Botte dell' Acqua, where the compact stone has a light grey base not unlike some trachytes, through which are scattered well-formed crystals of felspar and augite with some olivine. Let us now assume the narrowest of the recent lavas above mentioned near the summit of Etna to be 300 feet broad, and suppose one of the subordinate layers to be 8 feet thick, the analogy of all the sections above described leaves scarcely any doubt that it would consist of an upper scoriaceous crust, say 3 feet thick, a middle stony layer of about the same thickness, and a bottom scoriaceous stratum of 2 feet. The dip just below the edge of the platform is 24°, and we should then have a highly inclined tabular sheet of stony lava, which, in reference to its vertical and horizontal dimensions, would be in the proportion of 1 to 100, forming therefore a thin stratum. We have already considered (at p. 735, fig. 13) what would be the appearance of several such juxtaposed currents, if seen in a transverse section; but it should be borne in mind that we cannot look for a strict analogy in the breadth, average thickness, and degree of compactness in lavas of ancient and modern cones, unless we are able to compare sections of such cones at corresponding heights, which is usually impossible.

Flexures and arches in ancient lavas.

In order to guard against imagining a contrast between older and newer lavas, where none really exists, we must remember that the steeper the angle at which a current has cooled, the more parallel in general will be the planes of stratification of the several scoriaceous and stony layers which compose it. No doubt a great diversity of character prevails in this respect in lavas which have congealed on corresponding declivities, but I never met with ridges and furrows of great dimensions where the original slope exceeded an angle of 20°; and the rare occurrence of flexures on a gigantic scale in the steeply inclined lavas of the Val del Bove, has always appeared to me a fact in favour of the original steep dip of those lavas. We have already seen (p. 718, fig. 6, and p. 726, fig. 9, and p. 730) that the surfaces of the lavas of 1689 and 1852 are comparatively even and uniform where they have cooled on slopes of 30°, 35°, and 40°; whereas at points immediately contiguous, where the same currents have overflowed less inclined planes of 10° or 15°, they have been bent into gigantic folds and ridges. There may be exceptions to this rule, for some sharp and conspicuous flexures are visible in the escarpments of the Val del Bove, as for example, near the base of Monte Zoccolaro, in which there are two arches, one 15 and the other 20 feet high. So also in the northern escarpment above Rocca Capra (see Map II.), at about two-thirds of the height of the entire cliff above its base, a cave occurs 60 or 70 feet high, caused by the arching of

the lava and the washing out of the lower scoriæ. But these and other caves are exceptional, and the circumstances under which they occur deserve particular investigation, as they may perhaps be due to some local peculiarity in the external form of the ancient cone at such points.]∞

Dikes in the Val del Bove.

Dr. CARLO GEMMELLARO, in several of his memoirs on Mount Etna published in the years 1835, 1847, and 1854*, &c., has argued against the "Elevation-crater" hypothesis, by calling attention to the steepness of the slopes down which some of the modern lavas of Etna have flowed; and he has particularly insisted on a fact, first pointed out by his brother MARIO GEMMELLARO, that a great number of dikes radiate from the present centre of Mongibello. Baron S. VON WALTERSHAUSEN, during his patient explorations of Etna, has also observed (see above, p. 741), that many dikes, thirteen or more in number, composed of greenstone, converge in like manner towards an ancient centre, called by us the axis of Trifoglietto. Assuming that all these dikes have been originally vertical, or nearly so, they might retain their verticality even after upheaval, if they radiated in exactly the same directions as the movements which uplifted the strata so as to make them dip away quâquâversally from a central axis. But in that case we should be under the necessity of concluding that the upheaval of the principal centre, namely that of Mongibello, has not interfered with or disturbed the position of the beds dependent on the lesser and adjoining cone of Trifoglietto, a conclusion quite inconceivable. All observers agree that there are a multitude of dikes which do not radiate from either of the two principal centres above alluded to, and it is impossible to reconcile the prevailing perpendicularity of the dikes with the steep inclination of the lavas and fragmentary strata which these same dikes intersect, unless we abandon the upheaval theory. For if a set of horizontal strata traversed by vertical dikes, radiating from more than one centre, and by other dikes not converging to any single point, were uplifted so as to dip at angles of 20° and 30°, it is obvious that the dikes also must become as much inclined relatively to the horizon as are the strata, the only difference being that the dip of the dikes and of the strata would be in opposite directions†.

Of the first three dikes which I measured in the hill of Calanna, I found two which were vertical, the direction of one being south-west and of the other 30° east, while the third, which had also a south-east direction (on the side nearest to Zoccolaro), was no less than 30° out of the perpendicular, its dip or hade being 60° south-west. In the Serra del Solfizio and elsewhere I saw many dikes which were vertical, where the beds intersected by them were highly inclined, while other dikes which were out of the perpendicular, were not inclined in the direction which the upheaval theory would require, but often precisely the reverse, their hade being towards the same point of the compass as the

* Sulla Costituzione fisica dell' Etna, 1847; and others in the 'Atti della Acad. Gioenia.'

† See my statement of this argument, with a diagram, in the 6th vol. of the Geol. Quart. Journal, p. 231, 1850; and Principles of Geology, 9th edit. p. 418.

dip of the beds. In volcanos in general the frequent association of highly inclined lavas and of numerous dikes, does not imply that the injection of melted matter into fissures has tilted the beds, but that near the principal crater, where earthquakes rend the mountain and where lava is ever ready to flow into rents, there are causes at work, as already stated at p. 751, to produce a steep slope in the ejected and outpoured matter.

When we recede four or five miles from the great centres of eruption on Mount Etna, still continuing within the domain of the old lavas, as in the valleys of Calanna, S. Giacomo, and Cava Secca, we find very few dikes, only three in S. Giacomo, and one in Cava Secca, which last is more remote from the centre of eruption; at the same time the lavas begin to dip less steeply, and to form a much more considerable proportion of the whole mass. The lavas, indeed, in these sections are sometimes separated only by such scoriæ as may have formed the top crust of an older and the base of a newer current, or occasionally by tuffs chiefly of alluvial origin.

Lateral cones of Etna.

I was surprised at finding no clear indications of buried lateral cones in the walls of the Val del Bove, since there are so many in Madeira at great depths, some of them overwhelmed by an accumulation of lavas and tuffs more than 1000 feet in thickness. Whether some of the irregularities of stratification and dip seen in the great escarpments and in outliers, such as Finocchio Inferiore, accompanied by many dikes, may be connected with ancient points of local eruption, is a fit subject for future investigation. The evidence, so far as I was able to inquire, did not seem to me satisfactory, and I therefore infer that, at the period when the two permanent centres of eruption were active (those of Trifoglietto and Mongibello), whether contemporaneously or in succession, there were few if any lateral outbreaks. The great phase of lateral eruption seems to have begun about the time when the truncation of Mongibello and the gradual formation of the Val del Bove were in progress, and after much bodily upheaval of Etna and the adjoining country had been gradually brought about.

Baron S. von Waltershausen has remarked* that there are certain spaces within the volcanic region of Etna, where lateral cones are wanting, or nearly so, and others where they abound. Thus he observes that in the direction from Paternò to Bronte, from S.S.E. to N.N.W., and again from Aci Reale towards Linguagrossa, from N. to S. (see Map, Plate XLIX.), there are two zones, each of them about eight miles broad, *without* cones; and again, there are two zones nearly parallel to each other, running from S.E. to N.W., where lateral cones are in great profusion, the first from Monte Trigona to Monte Egitto, and the second from M. Cubania to M. Spagnuolo; and these directions he thinks have some relation to the larger axis of the central nucleus of Etna, and to the strike of a certain set of dikes which do not radiate from the centres, whether of Trifoglietto or Mongibello, before mentioned. A glance at the Map which accompanies this paper, reduced by permission from S. von Waltershausen's large 'Atlas,' will show that

* Atlas, V. and VI. p. 4.

a very considerable number of cones do, as he observes, run in the zone first alluded to, namely, from Monte Trigona to Monte Egitto; but the other parallel zone from Cubania to Spagnuolo is so short and comparatively unimportant, that we might draw another exactly at right angles to it (*e. g.* from Monte Peluso, S.E. of Bronte to Monte Santo, near Linguagrossa), which would comprehend a zone of twice the length, and embracing at least double the number of points of lateral eruption. On the other hand, if we take the summit of Etna or axis of Mongibello as a centre, and draw a circle round it having a radius of ten geographical miles, we find that nearly all the lateral cones, 200 or more in number, all carefully laid down by VON WALTERSHAUSEN, are embraced within this circular area, with the exception of a few south and south-east of Nicolosi, and one or two others in the north, such as Monte Santo and Mojo; so that when we speculate on the causes of the present distribution of lateral cones, we find more connexion between them and the position of the great central focus, than with any supposed linear clefts running N.W. and S.E.

If, again, we contemplate the Map in reference to the spread of the lavas and make a circle round the same great axis, with a radius of about twelve geographical miles, we embrace nearly all the currents which ever flowed from Etna, whether of modern or medieval, or older date, except those near Catania of 1669 and 1381.

This last fact may help to bear out the conclusion stated at page 742, that the present axis of Mongibello may be as old or older than that of Trifoglietto, and may have always been the chief focus of eruption.

∞[*Recapitulation of* PART II.

The following are the principal conclusions which I have endeavoured to establish in the second part of this memoir.

1st. The dip of the ancient beds of crystalline and fragmentary matter seen in the precipices surrounding the Val del Bove, are not such as to support the theory of a linear axis, nor of a single centre of upheaval for Mount Etna.

2ndly. The quâquâversal dip of the beds first observed by S. VON WALTERSHAUSEN away from an ancient centre, situated three miles to the east of the present summit of Etna, together with the horizontal or discordant dips of other superimposed lavas in the precipices at the head of the Val del Bove, imply the former existence of at least two permanent centres of eruption, and the final predominance of that which is still in activity, and which has overwhelmed the smaller or more eastern cone.

3rdly. The convergence of a large number of dikes towards the two supposed permanent centres of eruption is a fact corroborative of the theory above alluded to.

4thly. If such be the structure of Etna, and such the conclusions legitimately deducible from it, we must abandon the elevation-crater hypothesis; for although one cone of eruption may envelope and bury another cone of eruption, it is impossible for a cone of upheaval to mantle round and overwhelm another cone of upheaval so as to reduce the whole mass to one conical mountain.

5thly. The discontinuous and unconformable arrangement of certain parts of the ancient and modern products of Etna may be explained by supposing the former existence of two cones as above stated, and by the truncation of the ancient summit of the mountain, together with the contemporaneous or subsequent formation of the Val del Bove.

6thly. Although the cone-making process has mainly consisted of ordinary eruptions, yet the present steep dip of some of the old lavas and beds of scoriæ has been modified, especially near the ancient foci of eruption, by subsequent movements accompanying the rending and injection of the rocks, one-fifth perhaps of the present inclination of the beds being due to this cause, instead of four-fifths, as required by the elevation-crater hypothesis.

7thly. The alleged parallelism and uniform thickness of the beds in the escarpments of the Val del Bove, proves on closer inspection to be a delusion, for the lavas vary in strength and frequently thin out, being only persistent for great distances in the line of their dip, or the direction in which they originally flowed.

8thly. The ancient and highly inclined lavas are usually free from arches and flexures on a great scale, bearing a nearer resemblance to those parts of recent currents which have congealed on steep slopes than to those which have cooled on more level ground.

9thly. The scarcity of faults in the lavas of various ages, and the fact that the lavas do not cut through the dikes although the dikes so often cut through them, is opposed to the doctrine that a considerable amount of upheaval has been due to the injection of lavas in conformable sheets between pre-existing beds of tuff and scoriæ.

10thly. As the dikes are of various ages and do not all radiate from the two supposed centres of eruption, the verticality of so many of them is inconsistent with the elevation-crater hypothesis; for if the beds were originally horizontal, and owed their present steep dip to a final catastrophe, nearly all the dikes would be as much out of the perpendicular as are the intersected lavas and scoriæ.

Lastly. The absence of buried lateral cones in the escarpments of the Val del Bove, implies that the earlier eruptions were more concentrated and more limited to certain permanent vents than the modern ones.]ꝏ

PART III.

ON THE RELATION OF THE VOLCANIC ROCKS OF MOUNT ETNA TO THE ASSOCIATED ALLUVIAL AND MODERN TERTIARY DEPOSITS, WITH CONCLUDING REMARKS ON CRATERS OF ELEVATION.

Origin of the Val del Bove, and how far due to aqueous erosion.

The origin of that large crateriform valley, or Caldera, called the Val del Bove, so often alluded to in the foregoing pages, has been sometimes attributed to a great and sudden catastrophe connected with those movements which are supposed to have given rise to the mountain itself, and to have caused simultaneously the steep outward dip of

the beds sloping away on all sides from a central axis. But if the section, fig. 15, p. 740, represent with any approach to correctness the internal structure of Etna, and if the reasoning advanced in the foregoing pages be sound, the reader will have come to the conclusion, that the whole mountain, with its lavas and tuffs sloping away from more than one centre, and pierced by a succession of dikes, was already complete before the Val del Bove began to be formed.

In the first edition of my 'Principles of Geology,' published in 1830–33, I considered how far this great valley might be due to three causes,—1st, engulfment; 2ndly, explosion; and 3rdly, aqueous denudation; and I concluded that it was probably due for the most part to engulfment. At a later period (1849*) I suggested that the sea might perhaps have once entered the valley and exerted a denuding power, an opinion which I did not maintain in later editions of my two treatises on geology, and which I entirely abandoned after visiting Madeira and the Canary Islands in 1854, when I became aware of the prodigious excavating and removing power which torrents and rivers can exert on a volcanic mountain, when once eruptions have ceased. Mr. DANA had already called attention to this fact in reference to certain volcanos in the Sandwich Islands†; and M. ZIEGLER, the eminent Swiss geographer, after surveying Madeira and publishing a Map of the island, remarked in 1856 to Mr. HARTUNG and me, that inclinations such as characterize the river-channels of that island would be excessive and quite exceptional in the Alps.

It may, indeed, be said to hold true generally in regard to volcanic as contrasted with non-volcanic mountains, that whereas in the latter the valley-making power is at work during the whole period of their growth, that same agency only comes into play in subaërial volcanos after their completion. The volume of rain-water and melted snow absorbed annually by a lofty mountain like Etna is so enormous, that if at length the underground drainage is converted into a superficial one, the force of running water operates with what we may regard as a compensating intensity, as if the waters had the power of making up for lost time.

Alluvium of Giarre.—In the first part of this memoir it was stated, p. 709, that an alluvial formation on which Giarre and other towns are built, and which sometimes rises to the height of about 400 feet above the level of the sea, attests the removal at some unknown period in the history of Etna, of a vast quantity of stony fragments from that part of the mountain which lies immediately to the westward, that is to say, in the direction of the Val del Bove. If it could be shown that all this transported matter came down from the great valley itself, it would go far to prove that the abstraction of the missing rocks was for the most part effected by aqueous agency. To enable the reader to judge how far such a conclusion would be legitimate, we must compare the alluvial formations of the eastern and other sides of Etna, for by such a comparison it will appear that those at the eastern base of the mountain, and especially those opposite

* Quarterly Geological Journal, "On Craters of Denudation," &c., vol. vi. p. 207.

† Geology of the United States Exploring Expedition, 1842.

the Val del Bove, are conspicuous beyond the rest by their volume, and by being exclusively composed of the wreck of the volcano itself.

The coarsely stratified mass before alluded to (p. 709) as forming the terrace on which Giarre stands, would be called "diluvium" by some geologists, and much resembles the "glacial drift" of Northern Europe and America; yet with this important difference, that none of the blocks, whether rounded or angular, have as yet been observed to exhibit polished surfaces with rectilinear striæ or scratches such as might indicate a glacial origin. The largest angular fragments near Giarre are occasionally 9 feet in diameter. The blocks are of trachyte, basalt, dolerite, trachi-dolerite or grey stone, and agglomerate; in short, of every variety of rock met with in the Val del Bove,—some evidently derived from dikes.

A great torrent, dry for a large part of the year, which passes by Giarre, has cut a wide channel through this drift, to the depth of more than 40 feet, without reaching the bottom; and near Mangano, about four miles to the south, there is a section of a similar alluvium, 60 feet deep, with rounded and angular blocks, some of large size, occurring at a higher level, and overlying the Giarre deposit, making the thickness at that place in all probability more than 150 feet.

The alluvial region (*a*, *a'*, Plate XLIX.), to which the above-mentioned drift belongs, extends ten miles from north to south, and about three from east to west. It has been correctly laid down by S. von Waltershausen in his Map, of which Plate XLIX. is a reduced copy. The lavas flowing from the Val del Bove have covered and concealed from our view a portion of its western limits, as we may infer from sections seen between Santa Venerina and Santa Leonardello, in the banks of a torrent which flows down from Zafarana. But the northern half of the area alluded to (*a'* Map, Plate XLIX.), which reaches from Giarre to the Fiume Freddo, has not borrowed its materials from the Val del Bove, but must have derived them from parts of the mountain immediately north of the northern escarpment of the great Caldera. In that tract, however, the thickness of the drift, as well as the average size of the blocks, is visibly less than in *a*, for the transported fragments, as before stated, are most voluminous where they ought to be so on the supposition that the Val del Bove was their source.

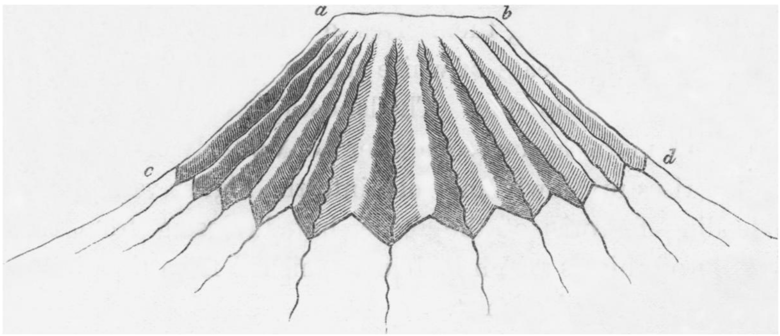
[*Valle del Tripodo, and proofs of aqueous erosion anterior to the Val del Bove.*

It may perhaps be suggested that the deposit of Giarre and Mangano might have been swept down by rivers from the old cone when it was still entire and before the Caldera originated, in favour of which theory it might be urged that in the Val del Bove at present we discover no action of running water capable of causing extensive denudation; also that we may well imagine, during some former suspension of eruptions on the eastern flank of the volcano, that ravines like the Cava Grande may have been gradually excavated in the wide space separating the two hills of Calanna and of Caliato.

In order to test the value of such an hypothesis, I determined to explore, from their

lower to their upper terminations, the two principal valleys of aqueous erosion which slope upwards from the foot of the cone to the southern margin of the Caldera.

Fig. 23.—*Furrows of aqueous erosion on the cone of Tengger* (from JUNGHUHN's 'Java,' vol. ii. part 2, p. 588).



Those who are conversant with JUNGHUHN's 'Volcanos of Java,' are well aware of the nature and value of this test; for they will remember that the flanks of volcanic cones which are in full activity are free from furrows eaten out by running water; whereas such as have been long extinct or are in a state of moderate activity, exhibit a great number of ravines, from 300 to 600 feet deep, excavated by torrents, and parted from each other by "ribs" or ridges of volcanic rocks, compared by JUNGHUHN to the spokes of an umbrella. All these furrows grow narrower and shallower when traced upwards, and come to an end before they reach the rim of the crater, as at *a*, *b*, in the great volcano called Tengger; whereas in such volcanic cones as have been truncated by explosions and subsidences, after considerable aqueous erosion, the rim is invariably indented, as would be the case if the line *c*, *d* represented the margin of such a cavity. On applying this test to Etna, I found that the crest of the southern escarpment of the Val del Bove, between the Montagnuola and Zoccolaro, was, as a general rule, very entire and unbroken, but that there were notches or abrupt depressions, several hundred feet deep, precisely at the two points where the upper ends of the valleys called the Val dei Zappini and the Valle del Tripodo (see Map, Plate L.) joined the crest. Hence it is natural to conclude that the valleys in question are of older date than the Val del Bove, and that their higher extremities were once prolonged towards the upper region of the cone, and were cut off when the Caldera was formed. Such an explanation, however, of the facts would be fatal to any theory which refers to a single catastrophe, or to any one mode of operation, whether slow or sudden, the upheaval of Etna, the tilting of the inclined beds, and the opening of the great cavity called the Val del Bove. The dividing "col" which parts the Valle del Tripodo, the largest of the two valleys above mentioned, from the Val del Bove, deserves the attention of every lover of the picturesque, as well as of every geologist, though my guides assured me that in their time they had never heard of its having been visited by any traveller. It may be reached from Zafarana without fatigue by the aid of mules in one day, returning in the evening. On one side of the narrow ridge, 6000 or 7000 feet above the sea, we look

back down a wooded and rocky alpine valley, while on the opposite or northern side, the wildest and most magnificent scenery of the Val del Bove lies at our feet. To our right are the precipices of the Serra del Solfizio extending to Zoccolaro; and to the left, the vast pinnacled and craggy promontories of rock, which jut out one behind the other, below the Montagnuola, presenting themselves in all their grandeur. Looking up, we see the summit of Etna with its wreath of white vapour streaming in the wind, while every other portion of the sky is a deep blue. The landscape is lighted up by a bright sunshine almost every autumnal morning, but soon after noon a body of fleecy clouds, formed first in the lower region, rises up slowly and rolls into the higher valley, hiding from view in succession the leading features of the scene, but disclosing from time to time some momentary glimpses of objects which had just vanished from the sight, until the whole are enveloped in one dense veil of mist.

In order fully to appreciate the depth and width of the two gaps made by the two valleys above alluded to, especially by the Valle del Tripodo,—breaks in the otherwise continuous southern rim of the Caldera,—it is necessary to look at them from a distance, or out at sea off Aci Castello. By their aid we see into the interior of the Val del Bove, from points where, but for these openings, that valley would be quite shut out from view.

The erosion of the Valle del Tripodo is still going on; and here we have an opportunity of studying a small inland delta at its mouth, and of learning by means of it how much matter has been brought down in a given time, or during the sixty-six years which have elapsed since 1792, when a powerful flow of lava crossed the lower extremity of the narrow valley and suddenly put a stop to all further transportation of alluvium to lower levels.

The waters of the torrent, even when most swollen, no sooner arrive at the margin of the lava, than they are instantly absorbed by its spongy, scoriaceous crust, and by the superficial rents and grottos in which it abounds. The engulfed waters continue their course underground, but the mud, sand, and boulders are all left behind, and already form a deposit, which may be called an inland delta (see the point marked "delta," Map, Plate L.). This deposit is several hundred feet long, 100 or more broad, and judging from the shape of the ground, 30 or 40 feet deep. It proves, on the one hand, how much erosion has gone on in little more than half a century; and on the other, how entirely all aqueous action ceases in areas once covered with fresh lava, and where a superficial drainage is turned into a subterranean one. The deep ravine-like valleys of S. Giacomo and Cava Secca, occurring about two and a half miles to the south-east of the Valle del Tripodo, may in like manner have been excavated by running water, and the process is still in full operation. Of this I became fully aware in October 1858, when, after heavy rains, I beheld the turbid waters which drain them rushing down like Alpine torrents, and saw and heard repeated avalanches of stones and mud descending from their steep sides, as well as from the precipices, in which they terminate abruptly at their upper ends; for they are not continued upwards, like the valleys of

Zappini and Tripodo above mentioned, as far as the margin of the Val del Bove. The origin of the neighbouring valley of Calanna is more doubtful. Although its head is closed in by a precipice called the Salto della Giumenta (fig. 10, p. 730), the cliffs of its southern side are prolonged in the upper part of Monte Zoccolaro, so as to join on to the southern escarpment of the Val del Bove. Perhaps there existed originally an upper valley of Calanna above the "Salto," before the external configuration and drainage of the old cone was totally altered by the formation of the Val del Bove. There may have been a fall of water, as there have been in modern times cascades of lava over the Salto, and such a fall may have hollowed out the valley by cutting its way backward as far as the precipice or Salto, just as the torrent of the Cava Grande is now causing its ravine to retrograde. If so, we may admit that other valleys may in like manner have furrowed the eastern slopes of the ancient cone between the hills of Calanna and Caliato, before the origin of the Val del Bove, in which case much alluvium would no doubt have been swept down to the sea or to its borders at that early epoch. But admitting the possibility of such erosion of early date, I nevertheless do not hesitate to attribute the bulk of the Giarre alluvium to the excavation of the Caldera itself, for reasons which will be more fully explained in the sequel.]

[Section of alluvium and basaltic lava between Giarre and La Macchia.

In order fully to understand the question last alluded to, I must describe a natural section of the rocks laid open by the torrent descending from La Macchia to Giarre. This I examined in company with Dr. MERCURIO and Signor G. G. GEMMELLARO in 1857, and revisited it in 1858. We observed that the alluvium, attaining a thickness of 40 feet in the vertical banks of the torrent in the suburbs of Giarre (see above, pp. 709, 710), reposes on volcanic tuffs thinly stratified, which in some places emerge in low hillocks above the level of the alluvial terrace. As we ascended the dry bed of the stream, we saw first a current of lava capping the alluvium, and together with it forming the cliff of the right bank; then on the left, higher up, a powerful mass of basaltic lava, 90 feet thick, in great part columnar, resting on 30 feet of tuff, the perpendicular section being 120 feet high. The subjacent tuff, at its junction with the columnar basalt, is burnt red. At this spot the two formations are not separated by any intervening gravel, but further up on the right bank, a bed of alluvium, 10 feet deep, with many rounded and some huge angular fragments, 9 feet in diameter, is seen between the basaltic lava and the older tuff. From a study of the whole section, the details of which, if given here, would detain us too long, it appears that an ancient water-course, having the same general direction as that now passing by La Macchia, was first cut deeply in stratified volcanic tuff. This channel, narrow at first or near La Macchia, widened as it approached the present site of Giarre, where it spread out into an alluvial plain or delta. A current of basaltic lava flowing down from the higher region, and probably from the Val del Bove, then filled up the old channel, accumulating in some places to a depth of 90 feet, sometimes resting directly on the gravel-bed of the torrent, sometimes immediately on the tuff which rose

up from beneath the gravel and formed the steep sides of the ravine. In the course of time the waters again excavated a new channel, deeper than the first one, but not always coinciding with it in all its windings, although mainly in the same direction. This new erosion passed through both the basalt and subjacent tuff, with or without the intervention of the ancient river-bed, according as the new water-course corresponded with or deviated from the older one. Lastly, the lava of the year 1284, called the "Sciara di femina morta," flowed, as will be seen by the Map, Plate XLIX, from the Val del Bove west of Milo, and then north of Ballo to La Macchia, entering the modern channel of the torrent below that town, and is now in its turn cut through by the torrent, as I saw when I revisited the section in 1858. From this last fact I infer, that as this mediæval lava came down to this point from the Val del Bove, so many of the antecedent floods of melted matter, and among them the basaltic current above alluded to, was derived from that region. They would naturally all follow the lowest levels of the then existing surface of the country, just as the waters draining the eastern slopes of Etna have done. For this reason the older lava filled the old river-bed, and afterwards the newer lava of 1284 reached the existing river-channel.

We might have expected that what was once an ancient alluvial plain near the sea should now form a terrace at Giarre 40 or 50 feet above the level of the existing drainage, because the whole region must have participated in that upward movement, of which we find so many proofs along the sea-coast. During the gradual rise of the land the waters would hollow out their new bed, through gravel and incumbent lava, more readily than if the levels had been stationary. Upon the whole, I come to the conclusion that the drift of Giarre bears the same relation to the Val del Bove which the fluviatile conglomerate of the Barranco de las Angustias bears to the Caldera of Palma in the Canaries; that conglomerate of Palma is 800 feet thick and 4 miles long, composed entirely of fragments of volcanic rocks, and associated, like that of Giarre, with recent lavas of modern date*.]∞

∞[*How far successive subsidences and explosions cooperated in forming the Val del Bove.*

But we can by no means attribute the origin of the Val del Bove, any more than the Caldera of Palma, exclusively to the action of running water. In the case of the great Etnean cavity, the northern and southern escarpments are too widely separated from each other, and the western boundary cliff, or Balzo del Trifoglietto (nearly 4000 feet high), is too lofty to allow of such an hypothesis. Some one or more local catastrophes of paroxysmal intensity may have given rise to the first breaches, which ended in producing this enormous cavity, occupying about one-sixth of the circumference of the great cone, a cavity to which there is nothing similar on the other sides of the volcano.

What, then, we must now inquire, were the peculiar and exceptional causes to which it owed its origin? I have already spoken of the Cisterna, an elliptical cavity, now about 120 feet deep, produced in the year 1792 on the platform of the Piano del Lago

* See 'Manual of Geology,' by the author, 5th edit. p. 507.

by the sinking of the ground, and again deepened, according to M. E. DE BEAUMONT, by a subsidence in 1832. I also saw at a still higher level, near the Philosopher's Tower, a fosse-like depression, already half-filled up by recent showers of ashes which is known to have originated during the same eruption of 1832. The great rent of Mascalucia, formed in 1381, is still open, a mile in length and from 20 to 30 feet deep. Another fissure, 6 feet broad and of unknown depth, was formed in the plain of San Lio in 1669, and is said to have been 12 miles long, reaching to near the summit of Etna. Similar openings on the steep parts of a cone might easily become water-courses, and give passage to floods during the winter's rain and the melting of the snow, and these might gradually deepen and widen such fissures. But it is also fair to speculate on another very powerful agency, which in certain phases of volcanic activity, as Mr. SCROPE has frequently suggested to me, would scarcely fail to come into play,—I mean paroxysmal explosions, like that of Vesuvius in the year 79, wholly unaccompanied by any outpouring of lava. There were repeated eruptions of this kind in the history of Vesuvius for centuries after the year 79; and if a great explosion happened to be lateral instead of central, or on the slope instead of the highest point of a cone, the new chasm being commanded by higher ground or by the region of snow, floods of water would at certain seasons sweep down into it, and might increase its dimensions. To account for the position of so great a cavity on one side only of a cone, we may, in the case of Etna, imagine a connexion between the Val del Bove and the old axis of Trifoglietto. The ancient habitual duct or chimney, situated at T in the wood-cut map (fig. 14, p. 739), may, like that of the ancient Vesuvius after being plugged up for ages, have again given passage to vast volumes of pent-up gases or steam, blowing up the incumbent lavas of Mongibello, which had filled the crater and overtopped the secondary cone (as shown in fig. 15, p. 740). Moreover, the accumulated snow and ice, and consequently the action of running water, may at some earlier period have been greater in the higher region, when the cone of Mongibello was larger and loftier, before its truncation, especially if the first excavation of the Val del Bove dates as far back as the close of the glacial period, or when the Alpine glaciers reached the plains of the Po; for at that time the climate of a Sicilian winter could hardly fail to have been colder than now.

Isolated outliers of ancient rock, such as Finocchio and Musara, are striking monuments of waste, helping to prove the former continuity of the northern escarpment of the Val del Bove in a southerly direction; but unfortunately for the geologist, the foundations of these outliers are so much concealed by recent lava, that we cannot determine whether the removal of the missing rocks was brought about chiefly by aqueous agency, or by engulfment, or by explosions, or by a combination of two or more of these causes.

The multitude of dikes projecting from 10 to 50 feet above the general level of the ground in every part of the escarpments, shows clearly to what an extent the softer and more destructible beds have wasted away by atmospheric and torrential action. Such dikes are records of the former existence of masses of rocks now no more, though we can still trace the exact shape of the fissures by which they were at one period traversed.

The lateral ravines also, mentioned at page 754, bear testimony to the removing power of running water, since the Val del Bove was bounded by lofty precipices.

Even the torrent in the suburbs of Giarre, which is usually dry, and the channel of which slopes towards the sea at an angle of less than 4°, had in October 1857 carried to some distance fragments of stone 9 feet in diameter, derived from the older drift of its banks. What, then, may not have been the force of running water in the woody zone, where the mean fall is 7° or 8°, if the whole drainage of the eastern slope of Etna, instead of being as now subterraneous, was for a time superficial, after a suspension for some thousands of years of the flowing of lava?

We have already explained why, in the present state of the Val del Bove, no denudation on a large scale can take place. The obliteration from the map of Sicily of the river Amenano by the lava of 1669, is a good illustration of the antagonism of aqueous erosion and volcanic activity. Previous to 1669, the inundations of that river were often destructive of houses in Catania; but from the era alluded to, the waters have always made their way underground, and flow out clear and transparent from the extremity of the lava in the harbour of the great city. In like manner, at some former period there may have existed many rivers in the Val del Bove like those now draining the Calderas of Palma and Tiraxana in the Canaries, and like them they may, after uniting, have issued by one principal gorge; yet they would inevitably be all effaced from the map, and the gorge filled up with stony matter, whenever the time arrived, during a new phase of eruption, for fresh floods of lava to traverse the Caldera.]ᴤ

Flood of 1755 *in the Val del Bove.*

The only well-authenticated instance of a great body of water having passed from the higher region of Etna through the Val del Bove to the sea, was in the year 1755. An eruption had taken place at the summit of the volcano in the month of March, a season when the top of the mountain was covered with snow. The Canon RECUPERO, a good observer and a man of great sagacity, was commissioned by CHARLES OF BOURBON, king of Naples, to report on the nature and cause of the catastrophe. He accordingly visited the Val del Bove in the month of June, three months after the event, and found that the channel of the recent flood, no less than two Sicilian miles broad, was still strewed over with sand and fragments of rock, to the depth of 40 palms*.

The volume of water in a length of one mile he estimated at 16 millions of cubic feet, and he says that it ran at the rate of a mile in a minute and a half for the first twelve miles. At the upper end of the Val del Bove, all the pre-existing inequalities of the ground, for a space of two miles in length and one in breadth, were perfectly levelled up and made quite even, and the marks of the passage of the flood were traceable from thence up the great precipice (or Balzo di Trifoglietto), to the Piano del Lago, or highest platform. RECUPERO, in his report, maintains that if all the snow on Etna, which he

* The *palm* in use in Sicily is $10\frac{1}{10}$ inches English: eight of these palms make one *canna*, and 720 canne one Sicilian mile.

affirms is never more than 4 feet deep (some chasms we presume excepted), were melted in one instant, which no current of lava could accomplish, it would not have supplied such a volume of water. He came therefore to the somewhat startling conclusion, that the water was vomited forth by the crater itself, and was driven out from some reservoir in the interior of Etna*.

It seems to me very unlikely that the Canon, who was on the ground within three months of the date of the catastrophe, should have been mistaken in regard to the region of the mountain whence the waters came. His conclusions on that head seem to have been legitimately deduced from the fact, that the wreck of the inundation was traceable continuously from the sea-shore at Riposto up to the highest cone or its neighbourhood. [I am therefore inclined to suspect that at the time of the eruption of 1755 there was upon the summit of Etna not only the winter's snow of that year, but many older layers of ice, alternating with volcanic sand and lava, at the foot or in the flanks of the cone, which were suddenly melted by the permeation through them of hot vapours, and the injection into them of melted matter. I stated in the first edition of my 'Principles of Geology,' that during my visit to Etna in 1828, I ascertained the existence of a glacier under lava near the Casa Inglese, on the S.E. side, near the base of the cone, and that it had been quarried during the previous summer, affording a supply of ice to the Catanians. On returning thirty years afterwards (September 1858), I found the same ice, a mass of unknown extent and thickness, still unmelted. It had been quarried only five years before to the depth of 4 feet on the very same spot. My guide told me that he had seen this mass of solid ice, the bottom of which they did not reach, and that it was overlaid by 10 feet of sand, and the sand again by lava.

If glaciers may thus endure for a series of years under volcanic sand and lava, the store of water which Recupero speculated upon as contained somewhere in the interior of the mountain, seems sufficiently accounted for. I am also now disposed to attach more importance than when I first wrote on this subject†, to the tales of the mountaineers, which Recupero thought worth recording. They related to him that the water was boiling, that it was as salt as the sea, and that it brought down with it sea-shells to the coast. Now it will be seen that the hypothesis above suggested would very naturally account for the water being hot, and it may have been impregnated with saline matter exhaled from fumeroles on the sides of the cone or from the crater itself during the eruption; and these exhalations, without giving to it the composition of sea-water, may have taken away its freshness. As to the story of the marine shells, if the flood, after issuing from the Val del Bove, cut deeply through the superficial lava or the alluvium between Milo and Giarre, it may possibly have reached a bed of subjacent newer pliocene clay at the height of 1000 or 1200 feet above the sea, washing out of it a great number of fossil shells of living species, strong enough to bear transportation as far as Riposto. But as the tertiary strata do not crop out anywhere at present in the region here alluded to, many of my geological readers will think it safer to ascribe this part of

* Recupero, Storia dell' Etna, p. 85.

† Principles of Geology, 3rd edition, vol. ii. p. 123.

the statement of the peasants to a love of the marvellous, in which, after an event of so unusual a nature as this deluge, they might be pardoned for indulging.

An occasional flood like that of 1755 would no doubt do more towards filling up than towards excavating the Val del Bove, yet a repetition of such catastrophes, provided the outpouring of fresh lava was suspended, could not fail to exert a great denuding power, and would unquestionably give rise to just such deposits as those marked *a* on the map, Plate XLIX., which are so conspicuous near Giarre and to the southward.]

Gradual rise of the sea-coast and inland cliffs at the eastern base of Etna.

The position now occupied by the deposits of alluvium last alluded to (*a* and *a'*, Plate XLIX.), the upper portion of which have attained in some places a height of more than 400 feet above the sea, is the natural consequence of the upheaval of the whole coast along the eastern base of Etna, so often mentioned in the preceding pages. This gradual elevation was inferred many years ago by S. v. WALTERSHAUSEN, from the occurrence of raised beaches containing shells of recent species, and from lithophagous perforations in the rocks*, and he traced these signs of elevation to the northward of the volcanic region; as, for example, at the church of St. Andrea, below Taormina, where the limestone is bored by lithodomi at the height of 135 French feet above the sea, and where sea-shells of living species are preserved in a raised beach. Dr. CARLO GEMMELLARO also discovered in the same place horizontal grooves in the Jurassic limestone of the coast several yards above the sea-level, like those now worn by the beating of the waves on the rocks. His son also, Signor GAETANO, called my attention, during our visit to the Isle of Cyclops in 1857, to a marine breccia filling rents in the Newer Pliocene clay, in which I saw shells, many of them retaining their colour, of the genera *Columbella*, *Cypræa*, *Buccinum*, *Anomia*, *Patella*, and others, all of species now abundant in the neighbouring sea. Both the Gasteropods and Lamellibranchiates were recognized by Signor GEMMELLARO, as being in their normal position at various heights, some about 13 French metres above the sea, and a calcareo-siliceous incrustation of the same age contains the holes and shells of *Modiola lithophaga*. There are also large blocks of rolled lava, invested with Serpulæ, reaching points 14 metres high†. On the adjoining coast, at Trezza and at Molino d'Aci, we saw similar phenomena, to which S. v. WALTERSHAUSEN refers in the fifth and sixth parts of his 'Atlas' (pp. 6 and 7).

If such a bodily upheaval of the country has been going on for a considerable period during the subaërial growth of Etna, we are entitled to look for signs of ancient sea-cliffs, now inland at different elevations, and accordingly we meet with them, as before remarked, p. 710, one above the other, in ascending from Catania towards Nicolosi, where we find, first, a lower terrace cut in tertiary clay, and then a higher one at Fasano, where the old line of cliff has been excavated in stratified volcanic tuffs at the height of

* See a memoir by that author, entitled "Ueber die Vulkanischen Ausbrüche in der Tertiär-Formation des Val di Noto," Göttingen, 1846.

† Geol. Quart. Journ. 1858, vol. xiv. p. 504.

about 600 feet above the sea, the top of the cliff rising still higher, especially when traced in a north-easterly direction towards Licatia and beyond it.

[Other terraces have been cut in the gravel of the tract marked *a* in the Map, Plate XLIX., at various levels. When we pass from *a* to *a'*, or to the northern portion of the same alluvial region beyond Giarre and Riposto, we find the transported blocks individually smaller than on the coast nearer the Val del Bove, and the aggregate volume of the accumulation less considerable. On arriving at the river Menessale, still further north, we enter another hydrographical basin, where the pebbles consist in part only of Etnean lavas, the rest being of sandstone and other tertiary or secondary rocks, forming a mass about 30 feet thick, on the steep banks of the Menessale, where, as at Giarre, an elevation of the ancient alluvial plain has probably taken place.]

[*Alluvium of the northern, south-western and southern base of Etna.*

Leaving the Menessale, I made a tour, in 1858, round the base of Etna to examine the alluvium on all sides, going first along the northern foot of the mountain by Linguagrossa, Mojo, and Randazzo, where I found no alluvial terraces resembling those of Giarre. At Randazzo, however, I observed some indications of a change of level, on the right bank of the river Alcantara, where a lava-current of unknown date and of rudely columnar structure, has at some former period invaded the old channel of the river. That channel was first excavated in sandstone, and since the lava filled it, the Alcantara has cut out a new bed, 15 feet below the old one, giving us now on the right bank the following section: first and lowest of all, sandstone in regular and highly inclined strata*, forming the lower part of the bank for a height of 15 feet; 2ndly, above the sandstone the old river gravel, with well-rounded pebbles; 3rdly, the columnar lava, ending upwards in a terrace, having a nearly level surface. The whole scene reminded me forcibly of Auvergne, where torrents have been displaced by lava-currents, which have protected the ancient fluviatile gravel from destruction, even where the valleys have been re-excavated beyond their original depth. The isolated cone of Mojo, which rises at the northern foot of Etna, and is supposed to have been formed about four centuries before the Christian era, but which, according to S. von Waltershausen, is of uncertain date, stands in the river-plain of the Alcantara, just as the cone of Tartaret and some others in Auvergne occupy the alluvial plains of the existing rivers, and, like them, has sent forth its stream of lava, since much denuded by the running waters.

Passing from Randazzo to Maletto and Bronte (see Map, Plate XLIX.), we observe nothing on the surface of the western flank of Etna but recent lavas; but turning to the south-west, and travelling by Adernò, Biancavilla, and Licodia, we enter the ancient basin of the Simeto, once evidently more extensive than now, its northern margin having been elevated many hundred feet above its original level. That margin, at a time when

* In these older sandstones, and some associated conglomerates and marls, whether at Randazzo or on the side of Bronte and Licodia, I could find no fossils. Hoffmann has given to them the general name of Apennine formations, comprising in that term the whole cretaceous and eocene series.

Etna was a volcano of smaller dimensions, was first overspread with alluvium, consisting of well-rounded pebbles of sandstone and other non-volcanic rocks, intermixed with a few of igneous origin, and afterwards overflowed by currents of lava, which still rest on the old gravel. The superimposed lavas, often rudely columnar, are now seen running out in long terraces from the south-western base of the great cone, and ending abruptly in cliffs which face the valley of the Simeto. Thus, for example, in the escarpment facing south-west between Biancavilla and Licodia, we observe above the fundamental rocks of sandstone and marl, first, a bed of pebbles resting unconformably on those ancient rocks; and 2ndly, the incumbent and semi-columnar dolerite.

Passing thence by Paternò and Misterbianco to Catania, we find still more conclusive evidence that the ancient littoral and delta-deposits of the Simeto and its tributaries have been upraised to very considerable heights above their original level, by movements which have also elevated the subjacent modern tertiaries in the country called the Terra Forte, south and west of Catania (see Map, Plate XLIX.). These same tertiaries, as we shall see in the sequel, also crop out along the eastern base of Etna, and contain marine shells, of which nearly nineteen-twentieths belong to species still living in the Mediterranean. The farther we recede from the southern foot of Etna towards the channel of the Simeto, the more dense become the accumulations of upraised pebbles. At Misterbianco, which I visited in company with Signor Gravina, they attain a thickness of 150 feet, and form the capping of hills, more than 600 feet above the sea-level. They are entirely different in shape and composition from that alluvium of exclusively Etnean origin, with angular fragments, occurring at *a a'* of the Map, Plate XLIX., for they consist of perfectly rounded pebbles of quartzose grit, nummulitic limestone and sandstone, fissile clay-slates, granite, gneiss, mica-schist, and a variety of other rocks, with a very moderate admixture of basalt*.

Some of the boulders of basalt, and some of those composed of hard tertiary grits, are 3 feet and upwards in diameter, but they are always well-rounded. They have evidently been derived from rivers which drained the western and central parts of Sicily, far beyond the precincts of Etna.]

[*Volcanic eruptions in the alluvial plain of the Simeto.*

At La Motta and Paternò we find within the area of the ancient estuary some highly interesting monuments of local volcanic eruptions, posterior in date to the great alluvium, for they have cast up some of the pebbles, so that they are enveloped in tuff or in lava, and often much burnt and altered. At La Motta, the summit of a basaltic and tufaceous hill thus formed is more than 900 feet high above the sea. The sites of this and of other local outbreaks in the same region are well laid down by Hoffmann in his Geological Map of Sicily. They were probably coeval with the earlier subaërial eruptions of the cone of Etna and with the tuffs of Fasano, of which I shall presently speak.

I have alluded particularly to the eruptions of La Motta and Paternò, because as they

* See a memoir by Signor B. Gravina, Bulletin de la Société Géol. de France, vol. iv. p. 403, 1858.

have burst out through tertiary clays covered with alluvium, no other changes have since occurred in the same region except those produced by fluviatile denudation, which, by removing a portion of the volcanic and other rocks, has enabled us to understand the relation of the former to the older formations. Here, therefore, we have an opportunity of testing the value of a speculation often hazarded by certain geologists, who wish to adopt, in a modified form, the theory of Elevation-Craters. They contend that however problematical the assumed terminal catastrophe may be, still the incipient convulsion must at any rate heave up the ground all round the orifice of eruption, and make the beds dip away in every direction from a central point, after which the new lavas and scoriæ as they were thrown out might mantle round the first-raised nucleus. But we find no warrant for such conjectures in the hills of Paternò and La Motta; nor did I see any in the more numerous sections of the volcanic and accompanying sedimentary rocks which I examined in 1828 in the Val di Noto, south of the plains of the Simeto. Yet the volcanos of that part of Sicily have burst out through marine tertiary formations horizontally stratified, and admirably fitted for upheaval into dome-shaped hills with crateriform openings at the top, if it were the nature of volcanic forces so to distend, lift up, and burst open the rocks which they inject. Instead of this, the melted matter seems to have simply made its way upwards through fissures, now constituting dikes, without producing any extraordinary dislocation of the rocks, and without making them dip at steep angles away from a central axis.]

cs[*Upraised fluviatile and marine deposits of the old estuary of the Simeto.*

The proximity of the land to the old estuary deposit of the Simeto is indicated by the tusks and teeth of elephants* found near Paternò, as well as at other places in the "Terra Forte" south of Catania, and frequently in digging the foundations of that city. Bones also of the horse, and of several species of bovine animals, and the teeth and horns of stags have been met with in the same places. I was also informed, that in the old alluvium of Cefali the molar of a hippopotamus had been found; but I had no opportunity of verifying these facts, or of getting the species determined by competent osteologists.

Signor B. GRAVINA, in a memoir recently published in the 'Bulletin' of the Geological Society of France (2nd series, tom. xv. p. 391, 1857–58), has recorded the discovery of a member of this same series of estuarine deposits which is of marine origin. He took me to see its exact position in 1858, in the neighbourhood of Misterbianco, where it is covered by the conglomerate. It consists of ferruginous sands and clays, which in the hill of Camuliu, between Misterbianco and Catania, contain a bank of oysters of a recent species (*Ostrea foliacea*), together with *Pecten varius* and *Anomia ephippium*. These marine sands rise to the height of more than 800 feet above the sea, while the neigh-

* The fossil elephant above alluded to is probably *Elephas antiquus*, FALCONER. To that species, Dr. FALCONER informs me (March 21, 1859), all the elephantine remains found in caves near Palermo, or between that city and Trapani, are referable, no vestige of *E. primigenius* having been seen by him in Sicily.

bouring hill of Cardillo, which is 900 feet high, is capped by old alluvium or conglomerate, having there a thickness of 60 feet. The height of such modern (and probably post-pliocene) formations, at the distance of about twenty-five English miles from the centre of Etna (or axis of Mongibello), has an important bearing on the theory of Elevation Craters, for some geologists have wished to connect the upheaval of the marine tertiary clays skirting the base of Etna, with movements supposed to have given rise to the cone itself and to the high inclination of the volcanic rocks; whereas the upheaval in question evidently extended to the plains of the Simeto in a southern, and, as we have seen before, to Taormina in a northern direction, and was rather of the nature of those movements by which great continents have been raised above the level of the sea.]∞

Leaf-bearing tuffs of Fasano near Catania.

It is probable that a portion of Etna which is of subaërial origin is coeval with the upraised alluvial and estuarine formations last mentioned, and that a still larger portion of the mountain is of posterior date. We find immediately north of Catania the marine tertiary clays and sands of Cefali, of the Newer Pliocene period (250 French feet above the sea), covered with alluvium resembling that of the Simeto, and at Fasano, at a height of more than 600 feet, the same clays are overlaid by tuffs of subaërial origin. Imbedded in these tuffs are found not only boulders of basalt, but well-rolled pebbles of sandstone and grit, identical with those of Misterbianco and other localities in the basin of the Simeto. The tuffs of Fasano, which are of considerable thickness, contain in abundance, as do the same beds at Licatia not far distant, the leaves of terrestrial plants, some of which I collected myself on the spot, and others were liberally presented to me by Signor Gravina and Professor Tornabene. As these fossils are the only ones yet obtained from the subaërial deposits of Etna, I was very desirous of having them carefully determined by a botanist of high authority, and accordingly submitted them to Professor Heer of Zürich, who has had the kindness to give me both drawings and descriptions of them, which will be found in the Appendix, p. 782, and in Plate LI. It appears from his examination of the best-preserved specimens, that three of the fossils may be identified with three living species, all indigenous to Sicily; namely, 1st, the *Laurus nobilis*, or Sweet Bay; 2ndly, *Myrtus communis*, or Common Myrtle; and 3rdly, *Pistacia lentiscus*, or Mastic Tree. To fix the age of these tuffs relatively to the mass of Etna, would be difficult, because they have been carried up gradually above their original level at the same time that the cone has been growing in size and height, and encroaching with its lavas on the area previously occupied by tuffs, and by the underlying tertiary clays. But I presume that these plants of Fasano flourished after the marine sands and clays of Camaliu were formed, and during or immediately after the period of the upraised alluvium or conglomerate of Misterbianco. They may therefore have been contemporaneous with the eruptions of La Motta and Paternò.

At Fasano these plant-bearing tuffs are very regular in their stratification, and dip at an angle of 11° towards the north-west, or directly towards the cone of Etna, an incli-

nation probably due to subsequent movements, and if so, exactly the reverse of that which the theory of a central upheaval capable of lifting up the cone of Mongibello would require.

Age of the Marine Tertiary Strata of Cefali, Catira and Nizzeti.

In order to determine within certain limits the geological age of the principal mass of Etna, we must endeavour to ascertain the true chronological place in the tertiary series of those marine strata which at various points along the eastern base of the mountain crop out from beneath the subaërial volcanic rocks.

I have already alluded to the occurrence of such fossiliferous clays in the district called "Terra Forte" immediately south of Catania, where they must have emerged from beneath the sea at a very modern period, because the hills composed of them are capped at the height of nearly a thousand feet, not only by unconformable alluvium, but by formations of about the same age as the alluvium containing recent species of marine shells. We again meet with clays like those of the Terra Forte, replete with fossil shells at Cefali in the northern suburbs of Catania, and find that in that place also they are covered unconformably by alluvial deposits like those of the Simeto, proving by their present elevated and insulated position that a considerable change has taken place in the physical geography of the country since they originated. At a short distance north of Cefali, we come to the inland cliff of Fasano, at the base of which we again observe the tertiary clay, while in the cliff itself are seen the overlying plant-bearing tuffs before mentioned, with imbedded pebbles, like those of the alluvium of the valley of the Simeto. When the Fasano cliff was formed, we must suppose the sea or the waters of the ancient estuary to have beat against its base, causing denudation, to which the tuffs could never have been exposed after they had once attained their present level (about 600 feet above the sea), and when the surrounding country had assumed its present configuration.

The most inland place, within the boundary of the volcanic region of Etna, where the tertiary strata crop out, is Catira, about two English miles N.N.E. of Fasano and four north of Catania, a point at which they also reach their greatest altitude, ascertained by S. v. Waltershausen to be 1180 French, or 1258 English feet above the sea.

I visited Catira in company with Signor Gravina and Signor Gaetano G. Gemmellaro in 1858. The last-mentioned geologist pointed out to me in the tertiary clay and sand, several pebbles of volcanic rock with serpulæ attached, implying that the strata were originally of littoral origin, and that some volcanic formation not only pre-existed, but had emerged in the neighbourhood so as to undergo some waste and supply pebbles to an adjoining beach.

At Catira these tertiary strata form three hills, capped with doleritic lava,—hills which are not due to any local movements of upheaval, but to the action of the sea, probably at the time when they were gradually emerging from the deep. Such eminences may once have formed a group of islands off the shore, as the Fariglioni or

Cyclopean islands do now, and in this manner we may explain the steep cliffs which they present in every direction, some facing landward and others seaward.

In order to understand geographically the other localities where the tertiary fossiliferous clays crop out at the base of Etna, we must return to Catania, and follow the coast which trends in a north-east direction (see Map, Plate XLIX.). There they first present themselves at Aci Castello, then again at Trezza opposite the Cyclopean Isles, and again a mile and a half north-west of that place, and about as far from the sea, at Nizzeti. At all these points, the marine clays and sands, sometimes reaching elevations between 500 and 600 feet above the sea, are associated with contemporaneous basaltic and other igneous products, the most ancient monuments of volcanic eruptions within the region of Etna.

During my first visit to Sicily in the year 1828, I collected at two of the above mentioned localities (Trezza and Nizzeti) as many fossil shells as I could then find, and submitted them to M. Deshayes of Paris, who referred them to sixty-five species, the names of which I published in the Appendix (p. 53) to the third volume of my 'Principles of Geology,' which appeared in 1833. I then stated (p. 79), as the result at which the eminent French conchologist had arrived, "that almost all the shells were identical with species now inhabiting the Mediterranean, and for the most part now frequent on the coast immediately adjacent."

A few years later Dr. Philippi visited Sicily, and in his 'Enumeratio Molluscorum Siciliæ,' published in 1836, gave lists of the shells found by him at Nizzeti and Cefali. From the first of these localities he obtained seventy-six species, four only of which he regarded as extinct, including *Murex vaginatus*, which I have now ascertained to be a living species. In his list of 109 shells from Cefali he marks eight as extinct, from which also we must deduct *Murex vaginatus*, so that according to his investigations the proportion of extinct is in the case of Nizzeti only four in the hundred, and about six in the case of Cefali.

On the occasion of my last visits to Catania in 1857 and 1858, I had the good fortune to make the acquaintance of Dr. Aradas, an eminent physician and naturalist, who possesses the finest collection yet formed of the Nizzeti shells, which he liberally placed at my disposal, allowing me to take them to Paris and London. At Paris I obtained once more, after an interval of thirty years, the kind assistance of my friend M. Deshayes, in determining the names of fossils from Mount Etna, consulting him especially on points on which Dr. Aradas had entertained doubts. With one or two corrections, I have printed in full, in the Appendix B, p. 783, this list, as drawn up by Dr. Aradas. He has indicated therein the relative abundance of each species, also which of them are extinct, or not at present known in the Mediterranean. The total number of species being 142, sixty-seven are marked as additions to Philippi's list from the same place. *Murex vaginatus* was given as extinct, it having been so regarded by Philippi; but M. Deshayes first informed me (October 1858) that he had seen a shell from the Mediterranean, which he believed to be identical, and Mr. Cuming has since shown me three

fine specimens in a fresh state not differing in the slightest particular from the Nizzeti fossil *.

Omitting this shell, we have eleven species out of 142 which are extinct; but when we endeavour to estimate the relative age of this formation, we must take into account not only the comparative number of living and extinct species, but also the relative number of individuals by which each species is represented. We then find that although the ground in most of the localities above enumerated is plentifully strewed over, especially after it has been washed by heavy rains, with fossil shells, not one of the extinct species, except *Buccinum semistriatum*, is met with in abundance. *Buccinum musivum* is rare; and as for the other nine, they are so excessively scarce, that most of them, if not all, are only known as yet by single individuals. It is true that the same may be said of some few even of the recent species, but the larger proportion of that class are very common. I never succeeded, when collecting myself at Cefali, Aci Castello, Trezza, and Nizzeti, during my three visits to Etna in 1828, 1857, and 1858, in picking up with my own hands any of the extinct species, except *Buccinum semistriatum* and *B. musivum*.

In regard to two others of the eleven shells enumerated by Dr. Aradas as extinct, namely, *Pyrula rusticola* and *Monodonta elegans*, Fauj., of each of which single individuals only, and those not in a perfect state, have been found, M. Deshayes observed to me that they agree perfectly in form and appearance with well-known Miocene fossils which he has received from Bordeaux; he therefore asked whether some mistake may not have been made, or if not, whether they might not have been washed out of an older tertiary formation in the neighbourhood and imbedded in the Nizzeti clays. In answer to this latter suggestion, it would, I think, be difficult so to explain away their presence; for the only other strata which I saw containing tertiary shells near the base of Etna occurred at the distance of about fifteen miles from Nizzeti, nearly due north, on the banks of the river Menessali, about three miles W.S.W. of Piedemonte. Here I obtained a sufficient number of species to satisfy me that the strata were older than those of Nizzeti and Cefali, although by no means referable to the Miocene era, but belonging rather to some Newer Pliocene beds, more ancient than the clays of Nizzeti.

In the Appendix C. (page 786) will be found a second list of 62 species of Mollusca and 3 Echinoderms from Catira, above mentioned, p. 777, given me by Signor Gaetano G. Gemmellaro, by whom they were collected and named. Excluding five of the species of mollusca, which Signor Gemmellaro could not determine specifically, there would

* *Murex vaginatus* is one of the few species on which some Italian geologists have relied for proving the antiquity of the marls of the volcanic island of Ischia, near Naples, to be much greater than that which I assigned to them after my visit to Naples in 1828. (See Bulletin de la Soc. Géol. de France, tom. xi. 2nd ser. p. 72, and tom. xiii. p. 285, and xxv. p. 362.) In the first edition of my 'Principles of Geology,' I classed these marls as Newer Pliocene (see Table, vol. iii. p. 61 and p. 126), and having re-examined Ischia in 1857, I maintain the correctness of my published opinion, namely, that these greenish and bluish marls, about 1700 feet above the sea, belong, like the sub-Etnean marine clays above described, to the newest part of the Newer Pliocene period. To class them therefore as *sub-Apennine* or Older Pliocene, would be a serious retrograde movement, and one against which I am glad to see that M. Puggaard has protested. Bulletin, 2me sér. tom. xiv. p. 336.

remain 57 species, of which five are extinct; a proportion of about 9 per cent., implying a somewhat greater divergence from the recent fauna than the other lists. One also of the three echinoderms, *Brissus cylindricus*, is only known as fossil; but as I have had no opportunity, aided by skilful conchologists, of comparing the fossils themselves named in this list with the large collections in the Museums of Paris and London, I am not sure that the Catira fossils, if subjected to a similar scrutiny, would not yield results in more exact harmony with those obtained from other localities. Signor GEMMELLARO himself stated to me, that not only do the majority of the Catira shells agree specifically with those now living in the Sicilian seas, but the individuals are of the same average size and aspect, which is not the case with those found fossil in some of the older tertiary formations in Sicily.

Modern date of the mass of Etna.

If asked to which of our British tertiary strata those of Nizzeti and Cefali approach most nearly in age, I have no hesitation in answering, the Norwich Crag; but the latter formation is probably the older of the two, its fossils appearing to diverge somewhat further from the fauna of our British seas, than do the shells of the Etnean localities above mentioned from the mollusca now inhabiting the Mediterranean. If so, the great mass of Etna, or all that is of subaërial origin, being newer than the Nizzeti clays, must be, geologically speaking, of extremely modern date. Its foundations were probably laid in the sea; and were in all likelihood contemporaneous with the basalts and other igneous products of the Cyclopean Isles and Aci Castello, which, as we have stated, belong to the period of the fossil shells of Nizzeti and Cefali. When that fauna flourished, the area where Etna now rises was probably a bay of the sea, afterwards converted into land by the outpouring of lava and scoriæ, as well as by the slow and simultaneous upheaval of the whole territory. During that gradual rise the ancient river-plain of the Simeto, in which were imbedded the remains of the elephant and other quadrupeds, together with certain marine strata (those of Camuliu) formed near the mouth of that river, acquired their present comparatively elevated position. The local eruptions of La Motta and Paternò took place about the same time, *i. e.* during or immediately after the deposition of the older alluvium, when also the leaf-bearing tuffs of Fasano were formed. In the course of the same long period of elevation, the cone of Trifoglietto, and probably the lower part of the cone of Mongibello, were built up. Still later the cone last mentioned, becoming the sole centre of activity, overwhelmed the eastern cone, and finally underwent in itself various transformations, including the truncation of its summit and the formation of the Val del Bove on its eastern flank. At length the phase of lateral eruptions, which is still in full vigour, closed this long succession of events—changes which may have required thousands of centuries for their development, although in the same lapse of time the molluscous fauna of the Mediterranean has scarcely undergone a twentieth part of one entire revolution.

We have seen that almost all the common shells of Nizzeti are of living species; but this is still more true of the fossil shells of the glacial epoch in Northern Europe and

America, which are nearly all, if not all, identical with mollusca still inhabiting the northern hemisphere. Notwithstanding which, a large part of the European area has been turned from sea into land, or from land into sea, since the commencement of that glacial period, while the present distribution of living species of plants and animals throughout the continents and islands has been entirely established since the time when the transportation of erratic blocks by ice took place.

Recapitulation of PART III., *and concluding remarks on "Craters-of-elevation."*

Having recapitulated, at pages 737 and 761, the principal conclusions arrived at in the first and second parts of this memoir, I shall now give a brief summary of those which I have endeavoured to establish in this third part.

1st. Some valleys or ravines were formed by aqueous erosion on the flanks of Etna before the existence of the Val del Bove, nevertheless a large proportion of the transported materials at the eastern base of the mountain was accumulated during the formation of that valley, which was in part due to aqueous erosion.

2ndly. The first depressions in which the Val del Bove originated may have been due to the sinking in of the ground, and also to lateral and paroxysmal explosions unaccompanied by the emission of lava.

3rdly. A gradual upward movement of the coast has carried up to considerable heights the more ancient alluvial formations at the eastern and southern base of Etna, together with the subjacent marine tertiary strata; and this movement continued down to very modern times, and perhaps still continues.

4thly. The alluvial deposits of the valley of the Simeto were both marine and fluviatile, the latter containing some remains of extinct terrestrial animals, but the whole probably of post-pliocene date, and coeval with the subaërial portion of Etna.

5thly. All the shells of the tertiary strata of the eastern base of Etna, which are abundant, belong, with one or two exceptions, to species now living in the Mediterranean, and the newer pliocene strata, in which they are imbedded, were probably coeval with the oldest foundations of Etna.

6thly. In certain tuffs, next in age to the older and most highly elevated alluvium, the remains of terrestrial plants of recent species occur.

Lastly. No connexion whatever can be traced between the *general* movement of upheaval which has accompanied the growth of Etna, and the conical or dome-like form of the mountain; and even where local eruptions have burst through the tertiary and alluvial strata, these last have not been lifted up in such a manner as to favour the hypothesis of craters of elevation.

Reverting now, in conclusion, to the phenomena described in Part I., by which the capability of lava to consolidate on steep slopes, and to form thereon continuous and tabular masses of crystalline rock, is demonstrated, I may observe, that we can henceforth dispense with the sudden and terminal catastrophe to which the leading dogma of a certain school of geologists would, if adopted, force us to resort, in order to account for the highly inclined beds in every large volcano. The chief question which still

remains to be worked out is, how far each mountain of igneous origin, whether having a double axis like Etna, or a single one like Vesuvius, may owe a part of its conical or dome-like form to a gradual distension of the mass brought about by the injection into it of many, and sometimes voluminous, dikes of melted matter; also how far the same agency may impart to the tuffs and lavas a steeper inclination than that which they had originally. The answer to such inquiries may perhaps be different in each separate cone; but whether one-fifth of the inclination, as I have suggested as possible in the case of Etna, or a greater or less amount be ascribable to this cause, I have come to the conviction that upheaval has nowhere played such a dominant part in the cone and crater-making process, as to warrant the use of the term "elevation-craters," instead of cones and craters of eruption. Such a designation, as well as the theory implied by it, would be alike inappropriate in the case of all the igneous mountains which I have seen, whether in Sicily or the Phlegrean Fields, or in the volcanic district of Rome or that of Central France, or lastly, of Madeira and the Canaries.

APPENDIX.—A.

REMARKS ON THE FOSSIL PLANTS FROM THE VOLCANIC TUFF OF FASANO NEAR CATANIA ON MOUNT ETNA, *extracted from a letter addressed to the author by Professor* OSWALD HEER, *of Zurich, dated April* 1858.

The leaves from the volcanic tuff of Etna belong to three species now living in Sicily, namely, *Laurus nobilis*, L., *Myrtus communis*, L., and *Pistacia lentiscus*, L.: the myrtles and laurel leaves are the commonest, and are probably those which you mention as having been mistaken for those of *Quercus ilex*, L.

DESCRIPTION OF THE SPECIES.

1. *Laurus nobilis*, L., fig. 3, Plate LI.—Several leaves, exactly agreeing with the living species. Leathery leaves, narrowing at the base into the leaf-stalk, border entire or sometimes wavy, the secondary nerves arched, the bodies of the leaves filled with a distinct network.

Easily to be distinguished from *Quercus ilex* by the narrowed base towards the leaf-stalk and the nervation.

2. *Myrtus communis*, L., figs. 4 and 5, Plate LI.—The most numerous of the leaves from Fasano. They have completely the characteristic nervation of myrtle leaves, a distinct border nerve, which runs parallel to the edge, and receives the numerous delicate secondary nerves. Here and there the nervillæ may also be detected. The secondary nerves appear to be rather more numerous than in the living myrtle.

There are two principal divisions:—

a. Fig. 4, Plate LI.—Leaves agreeing in size and form with the large-leaved myrtle of Italy and of our greenhouses. They are also pointed at the end.

b. Fig. 5, Plate LI.—The others, on the contrary, are much larger, and sometimes blunt at the end, such as are found in myrtles kept in greenhouses and wet soils. But

a distinct species cannot be made out of these large leaves, as they entirely agree in nervation with the others. These large leaves attain a length of 2 inches and a breadth of 1 inch, while the smaller ones are only 1 inch long by $\frac{1}{2}$ inch broad. The secondary nerves run almost parallel, and with a slight curve to the border nerve, and run into it at almost right angles. In the middle of the area they have a shortened secondary nerve, which over two-thirds of this area runs into a network. The border nerve is quite as strong as the secondary nerves; but the middle nerve, or midrib, is much stronger.

It is striking, that the secondary nerves are rather more distinct than in the living myrtle leaves; and this is in like manner the case in the leaves represented in nature-printing.

Here and there are seen fine dots close together which appear to belong to the leaf.

3. *Pistacia lentiscus*, figs. 1 and 2, Plate LI.—Several beautiful pinnated leaves. The general leaf-stalk is in some distinctly winged, while in others it is hardly to be observed. That this winged border has not always been preserved, is proved by the circumstance that it sometimes exists on one side and is wanting on the other. The stalk lies below this and forms a furrow, whilst the winged borders stand out a little or are placed slanting against the stalk. The leaves alternate, though for the most part nearly approximating; on each side four, rarely five, the end leaves wanting. The leaves are leathery, sessile, elliptical or long elliptical, narrowed at the base, somewhat inequilateral, generally the upper side narrower than the lower, as in *Pistacia lentiscus*. From the midrib proceed very delicate curved secondary nerves, which are frequently effaced. The size of the leaves varies from 7 lines in length and 3 lines in breadth, to as much as 14 lines in length and $5\frac{1}{2}$ lines in breadth. The edge of the leaves generally curled, and agreeing with the leaves of *Pistacia lentiscus*,—1st, in the leathery structure of the surface of the leaf; 2ndly, in the number and position of the leaflets; 3rdly, in the form of the sessile leaves; 4thly, in the winged leaf-stalk (in the living species the breadth of the wing-border is very variable); 5thly, in the nervation; and 6thly, in the rolled edge of the leaf.

I think, therefore, I have good ground for referring these leaves to the Mastic tree, although I was a long time in doubt about them.

B.

[List of Fossil Shells from Nizzeti near Aci Castello, found by Professor Andrea Aradas (see p. 778).

N.B. *The species marked with an asterisk are those which do not appear in the list published by* Philippi *in his 'Enumeratio Molluscorum Siciliæ,'* vol. ii. p. 262.

The species printed in italics are extinct, or not known as living.

Mactra triangula, Ren.; common.
*Mactra solida, L.; very rare.
Corbula nucleus, Lamk.; very common.
*Diplodonta apicalis, Philip.; very rare.
Tellina distorta, Poli; very rare.
*Lucina spinifera, Montag.; rare.

Astarte incrassata, Brocc.; very common.
Cytherea Chione (Venus), L.; rare.
*Cytherea multilamella, Lamk.; rare.
*Cytherea exoleta (Venus), L.; rare.
*Cytherea rudis, Poli; common.
*Cytherea Cyrilli, Scacc.; rare.
Venus fasciata, Donov.; common.
Venus verrucosa, L.; rare.
Venus radiata, Brocc.; very common.
*Venus gallinula, Lamk.; very rare.
*Venus gallina, L.; rare.
Cardium echinatum, L.; rare.
Cardium papillosum, Poli; very common.
Cardium lævigatum, L.; rare.
*Cardium sulcatum, Lamk.; rare.
*Cardium tuberculatum, L.; common.
Cardita aculeata, Poli; rare.
Cardita corbis, Phil.; very rare.
Arca lactea, L.; rare.
Arca diluvii, Lamk.; very rare.
*Arca navicularis, Brug.; rare.
Pectunculus glycimeris, Lamk.; rare.
Pectunculus pilosus, Lamk.; common.
Pectunculus violacescens, Lamk.; rare.
*Pectunculus nummarius (Arca), Brocc.; very rare.
Nucula sulcata, Bron.; common.
Nucula margaritacea, Lamk.; common.
*Nucula placentina, Lamk.; very rare.
*Nucula emarginata, Lamk.; very rare.
*Modiola lithophaga, Linn.
*Lima squamosa, Lamk.; very rare.
Pecten Jacobæus, L.; rare.
Pecten maximus, L.; very rare.
Pecten opercularis, L.; rare.
Pecten polymorphus, Bron.; common.
Pecten aspersus, Lamk.; very rare.
*Pecten varius, Lamk.; rare.
*Spondylus aculeatus, Chemn.; very rare.
*Ostrea cochlear, Poli; rare.
*Ostrea plicatula, L.; rare.
Anomia ephippium, L.; rare.
*Anomia margaritacea, Poli; very rare.
*Patella Rouxii, Payr.; rare.
*Patella ferruginea, Gmel.; rare.
*Patella cærulea, L.; rare.
*Pileopsis hungarica, Lamk.; rare.
Calyptrea vulgaris, Phil.; common.
Rissoa oblonga, Desm.; rare.
Rissoa calathiscus, Laskey; rare.
Rissoa Montagui, Payr.; rare.
Rissoa Bruguieri, Payr.; rare.
Natica millepunctata, Lamk.; common.
Natica sordida, Swains.; common.
Natica macilenta, Phil.; rare.
*Natica olla, M. de Serres; rare.
*Natica intricata, Donov.; rare.
*Natica Dilwynii, Payr.; common.
*Natica Guillemini?, Payr.; rare.
*Siliquaria anguina (Serpula), L.; very rare.
Scalaria planicosta, Bivona; very rare.
*Scalaria communis, Lamk.; rare.
Vermetus subcancellatus, Bivon.; rare.
Vermetus glomeratus, Bivon.; very rare.
*Fossarus *siculus* (Maravignia *sicula*), Aradas; very rare.
*Solarium stramineum, Gmel.; very rare.
Trochus conulus, L.; rare.
Trochus striatus, L.; rare.
Trochus rugosus, L.; common.
Trochus sanguineus, L.; very rare.
Trochus magus, L.; rare.
Trochus fanulum, Gm.; rare.
Trochus Guttadauri, Ph.; very rare.
*Trochus fragaroides (Monodonta), Lamk.; rare.
*Trochus divaricatus, L.; rare.
*Trochus crenulatus, Brocc.; rare.
*Trochus articulatus (Monodonta), Lamk.; rare.
*Trochus *dubius*, Arad.; very rare.

*Trochus Adansonii, PAYR.; rare.
*Monodonta elegans, FAUJ.†
Monodonta Jussieui, PAYR.; rare.
*Monodonta corallina (Trochus), L.; rare.
*Monodonta Vieilloti, PAYR.; rare.
*Monodonta Tinei-Calcara, ARAD.; very rare.
Turritella communis, RISS.; very common.
Cerithium vulgatum, BRUG.; rare.
Cerithium lima, BRUG.; rare.
Pleurotoma gracile, MONT.; rare.
Pleurotoma Vauquelini, PAYR.; rare.
*Pleurotoma undatiruga, BIVON.; very rare.
*Pleurotoma volutella, VALENC.; very rare.
*Pleurotoma elegans, SCACC.; rare.
*Cancellaria cancellata (Voluta), L.; very rare.
*Cancellaria *cassidea* (Voluta), BROCC.; very rare.
*Cancellaria *coronata*, SCACC.; very rare.
*Fasciolaria lignaria (Murex), L.; rare.
Fusus rostratus, OLIVI; rare.
Fusus craticulatus (Murex), BROCC.; common.
Fusus echinatus, SOWERBY; rare.
*Fusus lamellosus (Murex), DE CRISTOF. and JAN; rare.
*Fusus corneus (Murex), L.; rare.
*Pyrula *rusticula*?, BAST.; very rare.
Murex cristatus, BROCC.; rare.
Murex Edwardsii, MENK.; rare.
Murex vaginatus, DE CRISTOF. and JAN; rare.
Murex Trunculus, L.; rare.
*Murex Brandaris, L.; rare.
*Murex erinaceus, L.; rare.
*Murex *multilamellosus*, PHIL.; very rare.
*Ranella lanceolata, MENK.; very rare.
*Triton cutaceum, L.; very rare.
*Triton corrugatum, LAMK.; rare.
*Triton intermedium (Murex), BROCC.; very rare.
*Chenopus pes-pelecani (Strombus), L.; very common.
*Cassidaria tyrrhena (Buccinum), L.; rare.
Buccinum prismaticum, BROCC.; common.
Buccinum *musivum*, BROCC.; rare.
Buccinum ascanias, BRUG.; rare.
Buccinum variabile, PHIL.; rare.
Buccinum mutabile, L.; common.
Buccinum *semistriatum*, BROCC.; very common.
Buccinum neriteum, L.; rare.
Buccinum scriptum, L.; rare.
*Buccinum *striatum*, PHIL.; rare.
*Columbella rustica (Voluta), L.; rare.
Mitra lutescens, LAMK.; rare.
Mitra Savignyi, PAYR.; rare.
Mitra *scrobiculata*, BROCC.; very rare.
Ringicula auriculata, MENK.; very rare.
Cypræa coccinella, LAMK.; rare.
*Cypræa Pulex, SOLAND.: rare.
*Cypræa lurida, L.; very rare.
Conus mediterraneus, BRUG.; rare.
Dentalium dentale, L.; rare.
Dentalium multistriatum, DESH.; rare.
Dentalium entale, L.; rare.
Ditrupa subulata, DESH.; rare.]

† This fossil (see above, p. 779) is figured by BASTEROT, Bord. p. 31, t. 1. fig. 22, and has been described by Dr. ARADAS under the name of *Trochus Zuccarelli*.

C.

[LIST OF FOSSIL SHELLS AND ECHINODERMS FOUND AT CATIRA NEAR CATANIA, BY SIGNOR GAETANO G. GEMMELLARO (see above, p. 779).

N.B. *The species marked in italics are extinct, or not known as living.*

Mollusca.

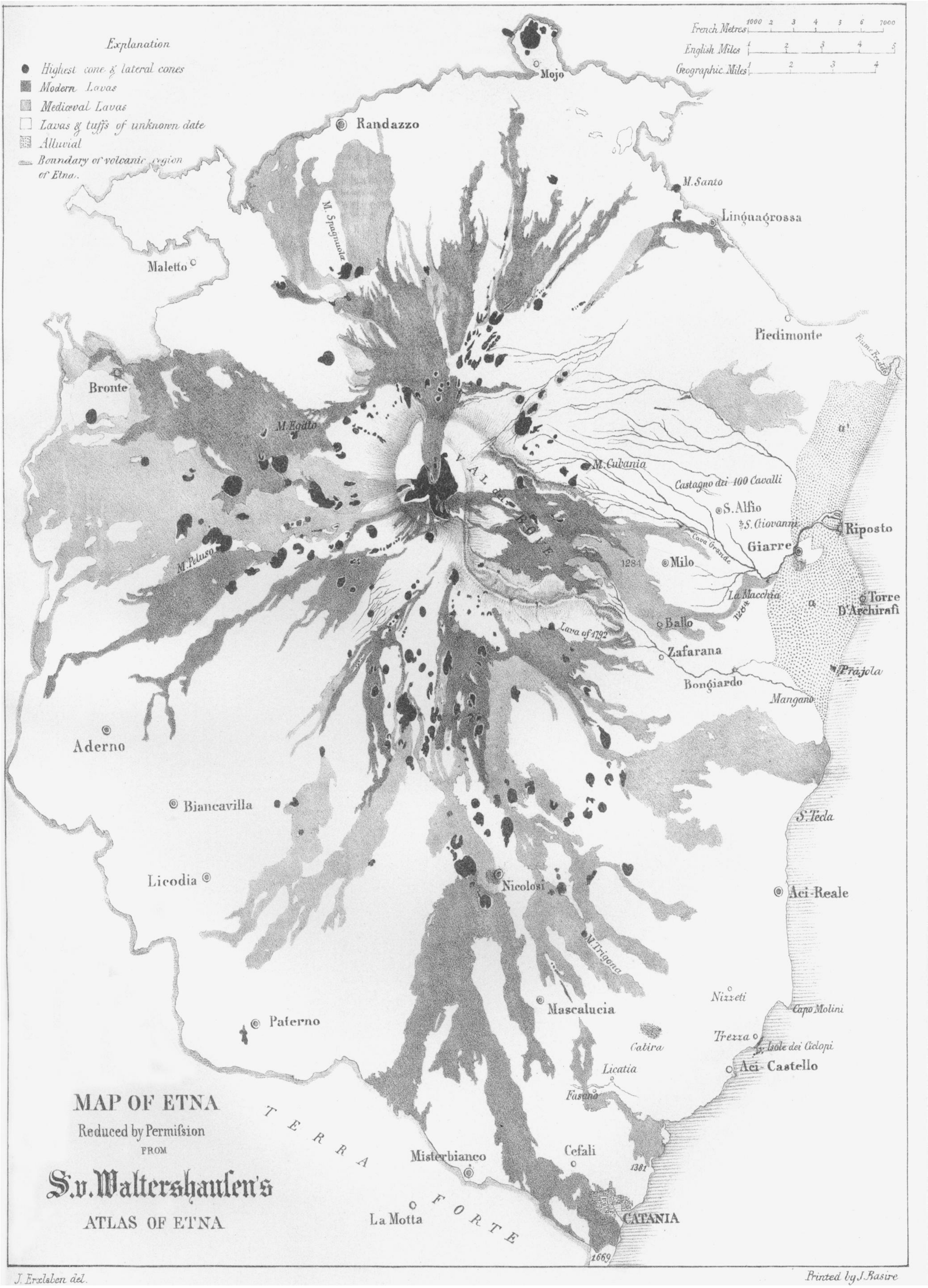
Solen coarctatus, L.
Corbula gibba, OLIVI.
Lutraria elliptica, LAMK.
Psammobia costulata, TURT.
Astarte incrassata, BROCC.
Venus radiata, BROCC.
Venus fasciata, DONOV.
Venus exoleta, L.
Venus *vetula*, BAST.
Venus verrucosa, L.
Venus Cyrilli, SCACC.
Cardium echinatum, L.
Cardium Deshayesii, PAYR.
Cardium sulcatum, LAMK.
Cardium lævigatum, L.
Cardium papillosum, POLI.
Cardita corbis, PHIL.
Pectunculus pilosus, LAMK.
Pectunculus glycimeris, LAMK.
Pectunculus *minutus*, PHIL.
Pectunculus *sulcatus*, POLI ?.
Nucula sulcata, BRONN.
Nucula margaritacea, LAMK.
Pecten Jacobæus, L.
Pecten opercularis, L.
Pecten polymorphus, BRONN.
Pecten aspersus, LAMK.
Pecten *palmatus* ?, LAMK.
Anomia ephippium, L.
Anomia polymorpha, PHIL.
Ostrea sp., not determinable.
Ostrea, sp. not determinable.
Calyptrea vulgaris, PHIL.
Natica millepunctata, LAMK.
Natica olla, M. DE SERRES.
Natica macilenta, PHIL.
Scalaria communis, LAMK.
Scalaria tenuicosta, MICHAUD.
Trochus magus, L.
Trochus Adansonii, PAYR.
Trochus conulus, L.
Trochus striatus, L.
Trochus lævigatus, PHIL.
Turritella communis, RISSO.
Cerithium lacteum, PHIL.
Fusus, sp. undetermined.
Murex Brandaris, L.
Murex Trunculus, L.
Aporrhais pes-pelecani, L.
Morio thyrrenus ?, GM. (Cassidaria).
Buccinum *semistriatum*, BROCC.
Buccinum mutabile, L.
Buccinum *striatum*, PHIL.
Buccinum ascanias, BRUG.
Buccinum variabile, PHIL.
Conus mediterraneus, BRUG.
Dentalium dentale, L.
Dentalium entale, L.
Dentalium multistriatum, DESH.
Dentalium, sp. undetermined.
Dentalium (Ditrupa) strangulatum, DESH.

Echinodermata.

Hemiaster canaliferus, D'ORB.
Brissus *cylindricus*, AGASS.
Echinocyamus Tarantinus, AGASS.]

ERRATUM.

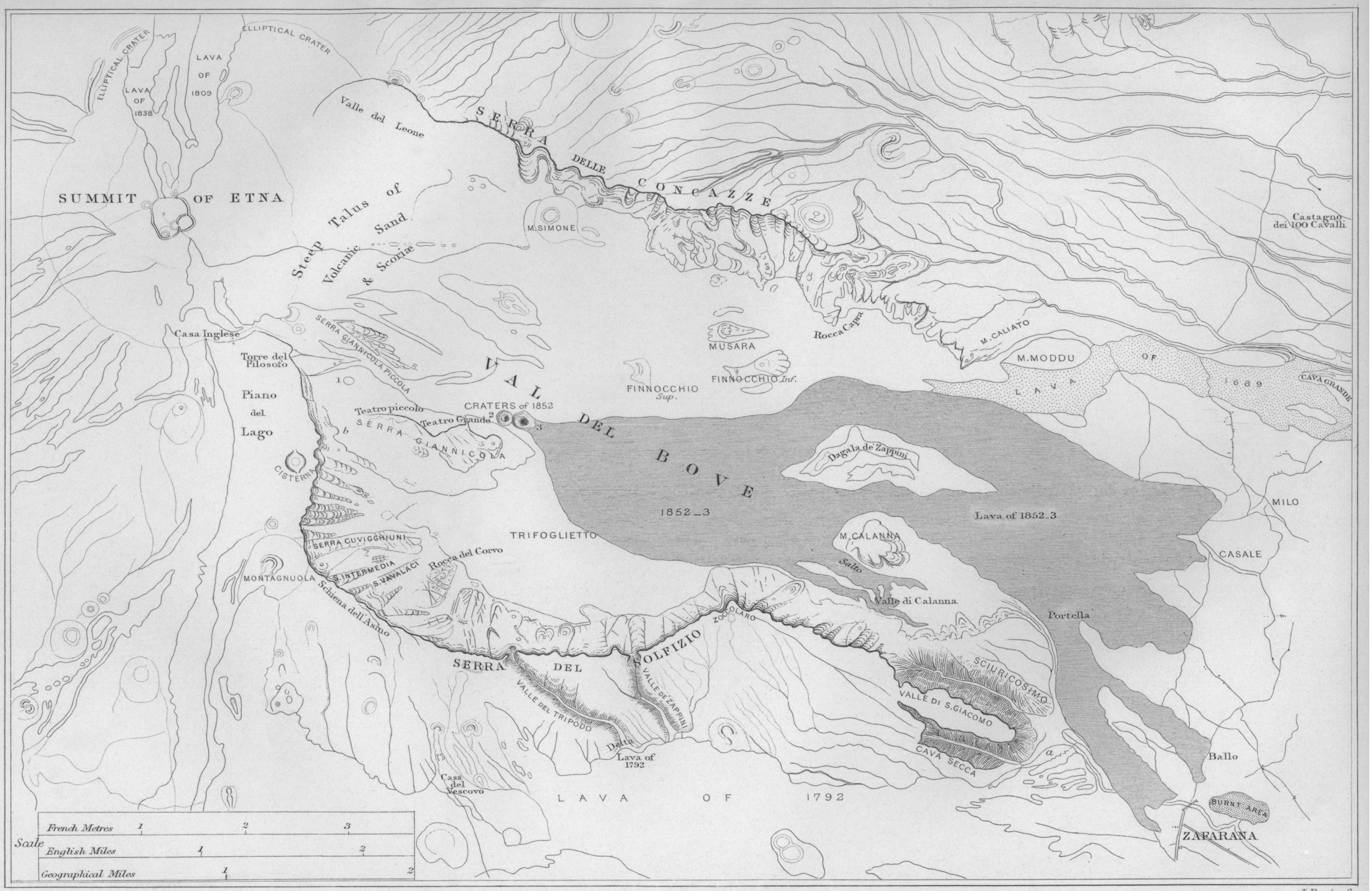
Page 708, line 24, *for* February 1850, *read* May 1855.



MAP OF ETNA
Reduced by Permission
FROM
S. v. Waltershausen's
ATLAS OF ETNA

J. Erxleben del.

Printed by J. Basire



CRATERS AND LAVA OF 1852, & 1853.

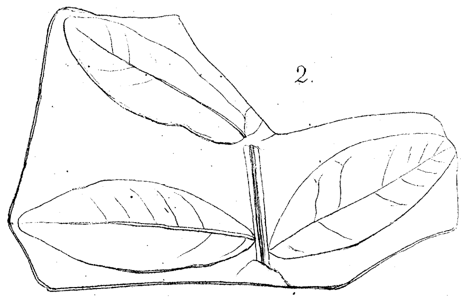
The Outlines *of the Map taken from S. Von Waltershausen's Atlas of Etna*

Fofsil leaves from the tuff of Fasano, Etna,

from drawings by Prof.r O. Heer.

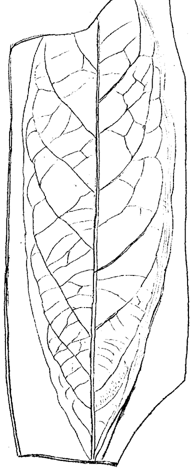
1.

2.

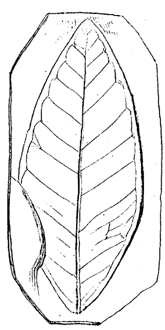


1. 2. *Pistacia Lentiscus L.*
Etna.

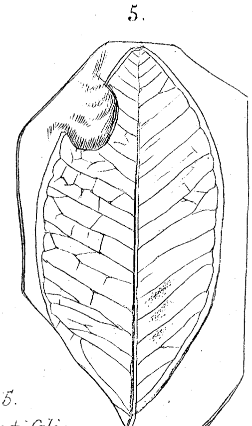
3.



4.



5.



5.
variet. latifolia.

3. *Laurus nobilis L.*
Etna.

4. 5. *Myrtus communis L.*
Etna.

J. Erxleben on Stone. Printed by J. Basire.